

TECHNICAL ASSESSMENT AND RECOMMENDATIONS FOR CHINOOK SALMON RECOVERY IN THE STILLAGUAMISH WATERSHED

**STILLAGUAMISH TECHNICAL ADVISORY GROUP
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This document was made possible by the hard work and commitment of the authors and their agencies over a three-year period. The contributors are listed in appendix D.

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This scientific report has been written as a guide for future salmon recovery efforts. It is not intended to represent an existing plan, course of action or program of the authoring agencies. It is the first step towards a multi-species salmonid plan resulting from broad based stakeholder participation.

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EXECUTIVE SUMMARY

A. INTRODUCTION

Chinook salmon (*Oncorhynchus tshawytscha*) were listed as threatened under the federal Endangered Species Act (ESA) in March 1999. Other anadromous fish species within the central Puget Sound region have since been listed (e.g. bull trout - *Salvelinus confluentus*) or are currently a candidate species (e.g. coho salmon - *Oncorhynchus kisutch*) for ESA protection. This report describes the effects of hatchery management, harvest, and historical land use on chinook salmon (chinook) populations in the Stillaguamish Watershed (Water Resource Inventory Area 5), which is located in the western Cascade Range and Puget Lowland of Washington state (Figure 1). Substantial evidence has been accumulated to document the decline of chinook salmon in the Stillaguamish and throughout Puget Sound.

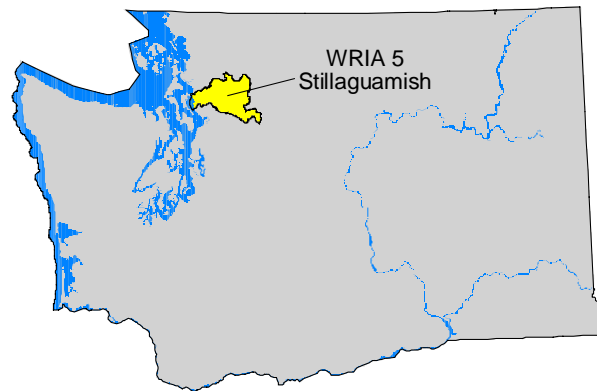


Figure 1. Location of Stillaguamish Watershed

This report is intended to provide a foundation for understanding chinook life history stages, the human-induced impacts on these life stages, and the technical basis for chinook recovery for the approximately 1,813 km² (700-square mile) watershed. Its objectives are to identify and quantify, to the extent possible: 1) historic resource conditions; 2) changes to this resource that have caused a threatened chinook status; 3) restoration goals for Stillaguamish chinook; 4) required modifications in hatchery, harvest, and habitat; and 5) a restoration strategy to achieve the identified changes. While providing a base of technical information and recommendations that focus on the measurable short-term and long-term benefits for chinook, this report also lays the groundwork for a multi-species salmonid recovery plan.

Approximately 25 individuals with technical and planning expertise in the watershed comprise the Stillaguamish Technical Advisory Group (STAG), which has provided the main contributions to this report. These individuals represent state and tribal fisheries co-managers and other private and non-profit organizations and agencies that affect habitat.

B. WATERSHED OVERVIEW

The Stillaguamish River drains an area of approximately 181,303 hectares (448,000 acres) and includes more than 7,432 km (4,618 miles) of streams and rivers. The river enters Puget Sound at Stanwood, 25 km (16 miles) north of Everett in northwest Snohomish County. Elevations in the watershed range from sea level to about 2,086 m (6,844 ft) on Whitehorse Mountain. The Stillaguamish Watershed can be divided into three general regions (Figure 2): the North Fork, South Fork and the Lower Mainstem. Pilchuck, Deer, and Canyon Creeks are the three largest tributaries to the Stillaguamish system.

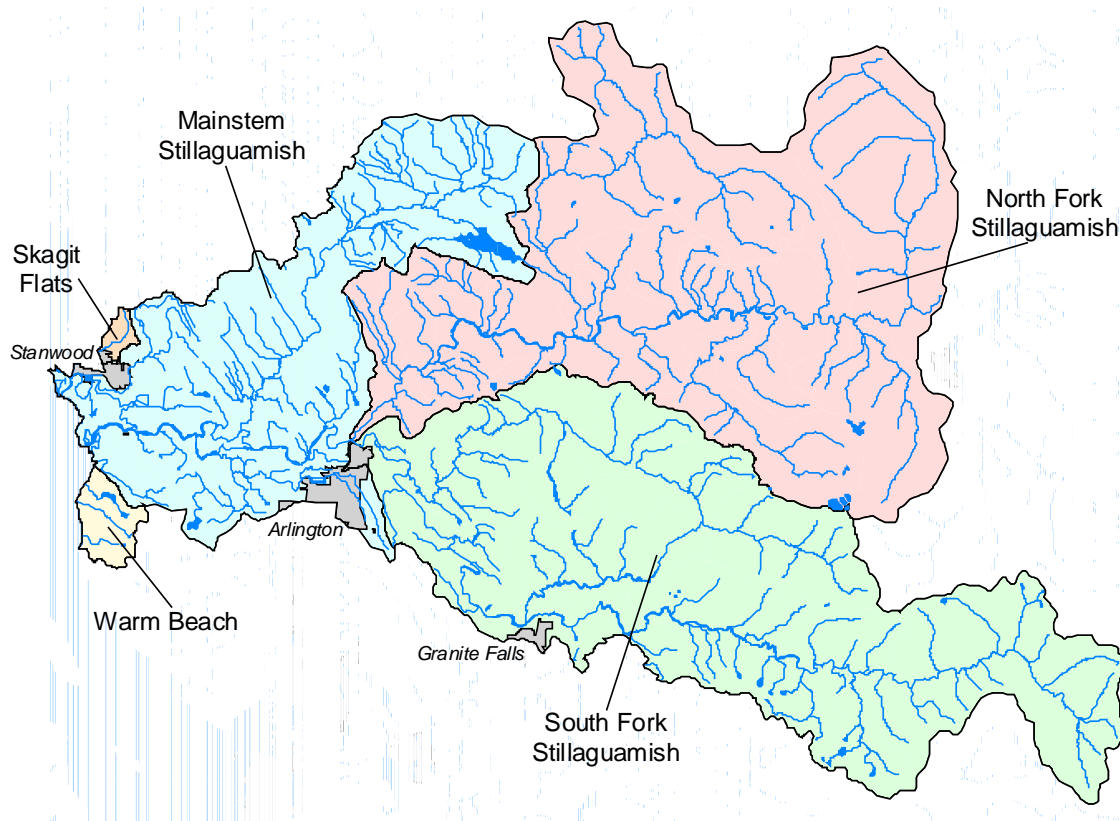


Figure 2. Stillaguamish Watershed

The climate is typically maritime with cool, wet winters and mild summers. Precipitation and streamflows are highest in late autumn and winter as a result of rainstorms and rain-on-snow events. During the summer dry period, the lowest flows occur usually from July through September.

C. STATUS OF THE CHINOOK SALMON POPULATION

Chinook salmon spend their earliest and latest life stages in freshwater river and stream habitats. Like many anadromous Pacific salmonids, chinook salmon spend most of their adult lives feeding in saltwater. The majority of adults return to freshwater as three and four year olds to reproduce.

Pre-development (1870) estimates of Stillaguamish chinook escapements (adult fish returning to spawn in the river) ranged from 9,700 to 13,321. This contrasts sharply with estimates of 400 to 1,550 returning fish for the years 1986-91 (Figure 3). Escapement figures from 1999 estimate only 1,098 returning adult chinook, falling well below the current escapement goal of 2000 fish (WDF 1977).

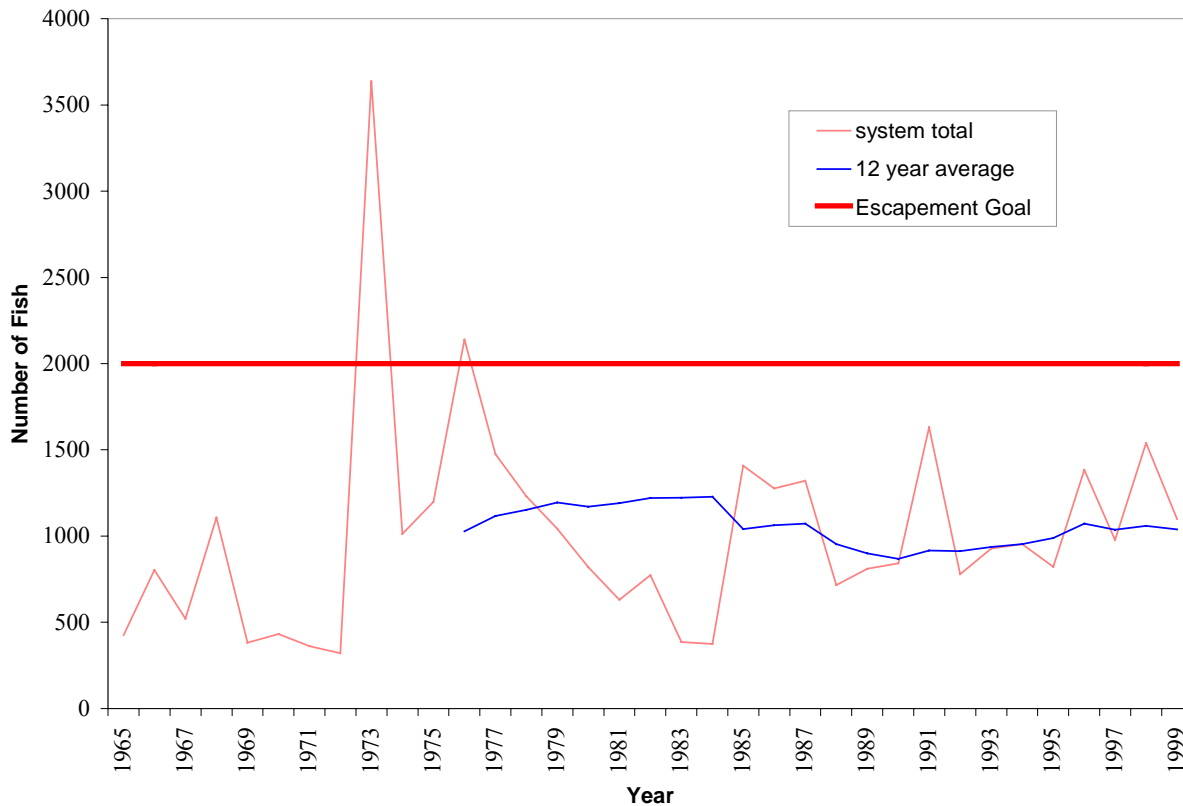


Figure 3. Summary of chinook salmon escapement in relation to the overall escapement goal in the Stillaguamish Watershed, 1965-1999.

Stillaguamish-origin chinook salmon are vulnerable to harvest in recreational and commercial fisheries throughout their adult range, from Alaska to the Puget Sound. Because the stocks are depressed, the Stillaguamish Tribe has not had a directed chinook salmon fishery in the Stillaguamish River for two decades. Since 1952, hatchery programs in the watershed have attempted to enhance fishing opportunities and mitigate habitat loss. The current tribal natural stock restoration program contributes an estimated one-third of the returning adults to the spawning habitat within the North Fork of the Stillaguamish River.

The National Marine Fisheries Service (NMFS) has determined that the Stillaguamish Chinook Natural Stock Restoration Program is one of the six essential hatchery programs within the Puget Sound necessary for recovery of the ESU. Based on NMFS' assessment of population decline and habitat degradation, the North Fork Stillaguamish stock would likely further decline and go extinct without the intervention of the natural stock restoration program (NMFS 1999).

D. FACTORS AFFECTING THE POPULATION

Historically, agricultural and forestry land uses were the source of most habitat loss in the Stillaguamish Watershed. Losses of estuarine salt marsh and tidal channels from reclamation of tidelands, constricted channels, and cut-off sloughs have significantly reduced the quantity and quality of juvenile and adult salmonid habitat. Furthermore, the long-term absence of mature riparian vegetation throughout the floodplain has had detrimental effects on existing habitat.

Riparian and upland clearing has led to large changes in channel morphology and peak flows, filling of holding pools, loss of wetlands, channel instability and a reduction in large woody debris (LWD). Most of these impacts have been caused by logging and road building in the forest zones. These activities have also resulted in increased fine sediment loads, which are known to be the primary cause of reduced salmon egg-to-fry survival.

Presently, conversion of existing forest and agricultural lands to rural residential and urban uses is a leading issue for salmon recovery. Human population pressures and growth near critical areas are leading mechanisms of landscape alteration. Stream hydrology, morphology, water quality, and ecology are all negatively impacted as permeable soils are compacted or covered by structures, concrete, and asphalt (i.e. impervious area). The cumulative effects of impervious area can result in poor stream habitat characteristics that do not support salmonids.

Incidental and directed harvest impacts have been a significant factor affecting Stillaguamish chinook for decades. Overall rates of exploitation have recently declined from 50-80% in the late 1970s to 25-35% in the late 1990s. State and tribal managers currently set maximum allowable exploitation rates, including all sources of fishery-related mortality affecting this stock, at levels that will not impede the ability of the stock to recover to healthy, sustainable levels of production.

The potential demographic impacts to wild populations from hatchery supplementation programs are also considerable. Hatchery-produced fish lack genetic vigor, transfer disease to wild fish, and may compete for food resources and space. Furthermore, increased hatchery production theoretically makes more fish available for harvest, resulting in increased harvest pressure on wild salmon intermingled in pre-terminal mixed stock fisheries.

E. DESIRED FUTURE CONDITIONS

The recovery goal for the Stillaguamish Watershed is to protect, restore, and enhance the abundance, geographic distribution, and diversity of all stocks of wild chinook salmon produced in the watershed to a level that will sustain fisheries, non-consumptive fish benefits, and other related cultural and ecological values.

The overall objective of listing the Puget Sound chinook as threatened is to restore the Evolutionarily Significant Unit (ESU) to a self-supporting population that does not require legal intervention to maintain its existence, while complying with other ESA requirements (NMFS 2000). Within the Stillaguamish Watershed, the primary objective is to restore chinook to a level

where natural stock production is healthy enough to support ceremonial, subsistence, recreational and commercial fish harvests. The relative health and viability of the population will be judged by its abundance, productivity, population structure, and diversity (NMFS 2000). These factors are essential to a viable salmon population and depend on properly functioning habitat.

1. Future Hatchery Operation

Future hatchery goals include maintaining the genetic integrity of both natural spawning populations within the Stillaguamish Watershed and the brood stock population used for the natural stock restoration program through continued genetic monitoring. Because it has been demonstrated to reduce the impacts of domestication within the hatchery and improve survivorship, the co-managers (WDFW & Tribes) will create more natural rearing conditions within the hatchery.

Another goal of the hatchery program is to assist the naturally spawning fish in rebuilding their numbers to a consistent, self-sustaining population that does not require human intervention in order for the population to support directed and incidental harvests. Co-managers will determine the future need and size of a chinook hatchery program to meet other management objectives such as the U.S./Canada Indicator Stock Program.

2. Future Harvest

Upon achieving recovery goals, fishery plans will be designed with the following considerations:

- Harvest-related mortality rates will be at or below levels that would jeopardize the populations.
- All sources of harvest-related mortality will be used to develop and evaluate harvest management plans.
- Risk buffering will be used to minimize the probability of over-harvest.
- Harvest-related mortality will not result in considerable alteration of important population characteristics.
- Maximum sustainable harvest (MSH) will set harvest levels no higher than the level that will, over the long term, provide the maximum level of harvest, given the above constraints.

3. Future Habitat Conditions

Habitat goals for the Stillaguamish include maintaining and restoring natural watershed processes and a dispersed and well connected network of high quality habitats. A long term strategy for the development and adaptation of land use activities to achieve these goals should be based on specific objectives. The performance targets below define properly functioning habitat conditions and should be used as the guiding scientific principles for salmon recovery.

Future Habitat Objectives:

- *Temperature:* Water temperature should not exceed 12-14°C (54-57°F).

- *Dissolved Oxygen*: Levels should exceed 5mg/l, and ideally be well above 8-9 mg/l.
- *Sediment*: Fine sediment (<0.85mm) concentrations should remain below 11%.
- *Channel Morphology*: Main channel habitat on the North Fork Stillaguamish should be increased by 38% including deep holding pools and LWD.
- *Hydrology*: Annual hydrographs display characteristics of base flow and flow timing comparable to historic (1870) watershed conditions.
- *Landslides*: Human-induced landslide activity reduced by 70%.
- *Wetlands*: Restore or create 70% of the lost wetland function.
- *Beaver Ponds*: Restore beavers and their associated ponds back to 50% of their historic levels.
- *Estuary/Blind Channel Habitat*: Restore or create 50% of the lost area back to fully functioning estuary/blind channel habitat conditions.

F. RECOMMENDED ACTIONS

1. Hatchery Management Plan

Hatchery reform goals are to conserve indigenous genetic resources, assist with the recovery of naturally spawning populations, provide for sustainable fisheries, conduct scientific research, and improve the quality and cost-effectiveness of hatchery programs (Gorton Science Advisory Team 1999).

Salmon and steelhead hatchery reform should be led in Washington State through the development of programs focused on: 1) adult fish, 2) natural stock genetics, 3) separation of hatchery and wild stocks, 4) monitoring of hatchery impacts, 5) research, 6) fish identification, and 7) adaptive management. Implementation of each of these components will increase the likelihood of salmon and steelhead hatcheries positively contributing to salmon recovery while continuing to provide commercial and recreational fishing opportunities.

Hatchery goals will increasingly be judged on how well they integrate salmon recovery, habitat protection and restoration, and the protection of other native species with the goals of harvest management. In contrast to historical periods, hatchery success will be measured by potential ecological effects (e.g. nutrient input from carcasses, competition with natural fish) instead of the number of fish produced (NWIFC 1996).

2. Harvest Management Plan

Consistent with the overall goal of this technical assessment, harvest of chinook salmon will occur in a manner that will have a low probability of impeding the capability of all natural stocks in the system to rebuild to levels that will support directed harvest and other benefits.

The primary components of the interim harvest management plan are: 1) maintain the exploitation rate on each brood below a level that, accounting for harvest, will not impede the ability of the stocks to rebuild; 2) maintain natural spawning escapement for each stock above a minimum level to assure the continued viability of the management unit; 3) reduce fishery-

induced size and age selectivity; and 4) establish recurring evaluation of harvest management and adaptation of the plan based on this information.

A program to collect and evaluate information necessary to develop a long-term harvest management plan for Stillaguamish chinook will continue. The plan will be based on updated assessments of system productivity and capacity. The most important part of the plan will be production functions for each stock relating recruitment biomass to the biomass of fertilized eggs on the spawning grounds. The long-term harvest management plan will be designed to provide long-term maximum sustainable harvest for the entire management unit, under the constraint that the viability and diversity of the production of each stock will not be jeopardized.

3. Habitat Management Plan

The degradation or complete loss of habitat is generally caused by direct human impacts that disrupt natural habitat-forming processes. In the Stillaguamish Watershed, these impacts are exhibited in riparian vegetation, channel morphology, and water quality/quantity, disrupting watershed-scale processes and reducing overall habitat quality. Developing a successful habitat management plan will require a greater understanding of the complex relationships between land use practices, watershed-scale processes, and chinook habitat requirements. Coupling available historical information with future research (while implementing a campaign of protection, enforcement, and restoration actions) will help land managers define clear and attainable recovery goals for chinook salmon.

Habitat recovery objectives for the Stillaguamish Watershed are: 1) maintain and restore natural watershed processes; 2) maintain a dispersed and interconnected network of high quality habitat that addresses the needs of all life history stages of chinook; and 3) monitor and evaluate certain land use activities so that they can be adapted (where possible) to achieve specific objectives outlined in the document.

Recovery Actions

A complete recovery strategy should outline specific actions and measures for each habitat problem that limits chinook productivity. Each known or suspected habitat problem and the focus of specific actions within the document are outlined below (not listed in priority order):

- a) **Loss and Degradation of Riparian/Shoreline/Floodplain Vegetation and LWD Recruitment** – actions that focus on enhancing riparian areas, promoting retention of mature forest characteristics, and restoring hydrologic connectivity.
- b) **Loss and Degradation of In-channel and Off-channel Rearing Habitat** – actions that focus on maintaining mature forest cover, maintaining low impervious surfaces, and allowing channel migration.
- c) **Loss and Degradation of Estuary and Near Shore Habitat** - actions that focus on the restoration and enhancement of lost or degraded estuarine habitat areas and conditions preferred by chinook juveniles.

- d) **Loss and Degradation of Spawning Habitat** – actions that focus on the restoration of natural hydrologic and sediment regimes, wood recruitment, and channel migration.
- e) **Loss of Large and Deep Holding Pools for Adult Chinook** – actions that focus on improving capacity of riparian area to contribute large woody debris.
- f) **Degradation of Water Quality** – actions that focus on decreasing sediment, increasing hydrologic connectivity and enhancing riparian areas and wetlands.

Chinook salmon recovery will require specific protection, enforcement, and restoration actions that address the root causes of the problem rather than the visible effects.

Protection: Acquiring land use and development rights through conservation easements, land use plans or fee simple purchases should be a core protective action. An acquisition strategy should prioritize properties based on their restoration potential, ecosystem connectivity and threat of development. Additional protection can also be achieved through the revision of aquatic and land use regulations, such as local, state, and federal regulations that are intended to provide protective measures for riparian, floodplain, and near shore habitats. Regulatory frameworks should be assessed with the intent to revise (where necessary): shoreline master plans, hydraulic code, stormwater management, best management practices for farm and rural landowners, critical areas and grading ordinances, zoning, comprehensive plans, and the growth management act.

Enforcement: Increased compliance to aquatic and land use regulations should also be pursued through improved enforcement. Hiring additional enforcement staff and empowering them to enforce regulations will help increase compliance levels. To further increase compliance, enforcement needs to be accompanied by effective prosecution. Increasing inter-jurisdictional cooperation and uncoupling enforcement capacity from administrative constraints will increase the productivity and effectiveness of agencies responsible for enforcing regulations.

Restoration: Effective restoration actions should target fish production bottlenecks and work to restore natural processes that produce and maintain habitat and increase chinook productivity. Restoration efforts aimed at reducing or limiting road densities in landslide prone areas, stabilizing major fine sediment sources (e.g. major landslides), and disconnecting road drainage networks from natural hydrology will address sediment issues that are limiting chinook productivity in the Stillaguamish Watershed. Reconnecting isolated habitats and enhancing riparian areas to restore natural wood recruitment and habitat connectivity will increase habitat availability and complexity for multiple life history stages of chinook. Increasing sediment filtration, ground water recharge, and stormwater retention can be achieved through detention facility maintenance and wetland restoration.

G. NEXT STEPS

Developing and implementing the full range of specific actions to recover chinook salmon will take time. However, much of the guidance in this document can achieve measurable goals in the

short term. Jurisdictions and entities with the ability and responsibility to recovery chinook salmon and comply with the ESA should find this comprehensive technical assessment an invaluable guide.

This document will be released to the public in the Fall of 2000. The STAG will then initiate multi-species reconnaissance in the winter of 2001 and begin drafting a multi-species technical assessment built on a chinook salmon foundation. By the fall of 2001, the elements of a multi-species plan will begin to take form. Specific actions to recover and sustain salmonids in the Stillaguamish Watershed will be included. A final multi-species plan and related agreements are scheduled to be adopted by 2003.

The complete plan to manage threatened salmonid stocks will involve the full participation of Stillaguamish stakeholders and jurisdictions that will implement salmonid recovery actions. The involvement of the Stillaguamish Implementation Review Committee (SIRC) will be a key part of this planning effort. Jurisdictions will also have additional opportunities to comment on actions and to propose initiatives that contribute to fish recovery. The Stillaguamish salmonid plan will borrow from regional frameworks, to the extent possible, in pursuit of regional ESU goals and to promote consistent policies that recover salmonids and their habitats.

I. INTRODUCTION

A. FOCUS AND PHILOSOPHY

This report is a guiding scientific strategy for chinook salmon recovery, in terms of harvest, hatchery, and habitat for the Stillaguamish Watershed (Water Resource Inventory Area 5). This document does not constitute a recovery plan, but instead provides the technical guidelines necessary to direct recovery plan development. Content is based on analysis of the historical and present status of Stillaguamish chinook salmon and their habitat along with recommendations on how to recover the species to harvestable levels. Although this document focuses on chinook salmon (*Oncorhynchus tshawytscha*), it also provides a foundation for the future development of a multi-species recovery plan.

B. ENDANGERED SPECIES ACT LISTING

Puget Sound chinook salmon were listed as threatened in March 1999 under the federal Endangered Species Act (ESA). In July 2000, the National Marine Fisheries Service (NMFS) issued the final 4(d) Rule designed to prevent chinook salmon from becoming endangered. Non-exempt activities that harm or take chinook or their habitat will be prohibited after January 8th, 2000. The primary purpose of this report is to lay the foundation for a multi-species salmonid recovery plan that is consistent with ESA standards.

C. RELATIONSHIP TO STATE, ESU, AND CENTRAL PUGET SOUND EFFORTS

Many different entities have authority over the factors that contribute to the decline of Stillaguamish chinook salmon. The State of Washington and the Washington State Treaty Tribes are co-managers of salmon harvest and operate most salmon hatcheries. A host of others including the United States Forest Service (USFS), Washington Department of Natural Resources (WDNR), counties, cities, and private landowners have jurisdiction in areas that influence habitat conditions.

Several species of salmonids have been listed under the ESA and are proposed for listing throughout much of Washington State. In order to develop a comprehensive strategy, the State has proposed a statewide salmonid recovery plan that covers multiple species and Evolutionary Significant Units (ESUs). Evolutionary Significant Units were established by NMFS as distinct population groups that can receive ESA coverage. The Puget Sound chinook salmon ESU covers all chinook salmon stocks in the Puget Sound region from the North Fork Nooksack River to the Elwha River on the Olympic Peninsula. The State's plan includes sections for a regional response within the Central Puget Sound area as well as watershed-specific actions. This report provides basic technical information that could be used in a State Plan.

This document also provides source material for a Central Puget Sound response. In early 1999, local governments, tribes, and private organizations came together to form the Tri-County Coalition. This voluntary, public/private coalition shares information, coordinates recovery planning, and consolidates communication with NMFS within Washington State's most populous areas. The Tri-County effort relies on public and private organizations in local watersheds to develop most of the technical information and public involvement for a Central Puget Sound chinook salmon recovery strategy.

A comprehensive recovery strategy must include all factors that contribute to the decline of Stillaguamish chinook salmon, as well as the public and private entities with authority over those factors. Thus, a variety of public and private interests and jurisdictions (Figure 4) participated in the development of this document including citizens and county, state, and tribal staff. In addition, this report includes recommended actions to be implemented by public and private interests that affect chinook salmon harvest, hatcheries, and habitat.

D. TECHNICAL ASSESSMENT APPROACH

This report is a major first step toward a multi-species salmonid recovery plan in the Stillaguamish Watershed. The technical assessment draws from a solid foundation of past studies, recognizing that future research will fill important data gaps.

Participation in Report Development

The Stillaguamish Watershed is fortunate to have a well-established public involvement and interagency coordination process that serves as a foundation for this technical assessment. This process was designed to develop a comprehensive recovery plan as well as meet the more narrow purposes of related state legislation (ESHB 2496). Major involvement efforts include:

- Stakeholders The long-standing Stillaguamish Implementation Review Committee (SIRC) was established as a result of the 1990 clean water action plan and acts as a forum to incorporate the viewpoints of citizens and interest groups in the watershed. Beginning in January 1999, a portion of the group met to resolve chinook recovery issues.
- Technical Committee The Stillaguamish Technical Advisory Group (STAG) comprised of technical staff from tribal, federal, state, and local resource management agencies started the latest chinook recovery planning effort in late 1997. In March 1998, this committee invited organizations with habitat-related responsibilities to join with them to develop a technical assessment report. Committee members met at least monthly beginning in March 1998. In September 1998, Washington Conservation Commission staff responsible for developing a limiting factors analysis under the Salmon Recovery Act, joined with the committee, which was then designated as the Technical Advisory Group for the purposes of ESHB 2496.

E. PUBLIC EDUCATION/PUBLIC ROLE IN SALMON RECOVERY

While protection, restoration, and enforcement will go a long way in helping depressed salmon stocks recover, an informed public is also critical to fully achieving chinook salmon recovery and cannot be overlooked. The Governor's Salmon Recovery Office acknowledges the public's role in salmon recovery and considers public support a necessary component to the success of salmon protection/restoration programs.

The goal of the statewide education efforts is to inform, build support, involve, and mobilize citizens to assist in restoration, conservation, and enhancement of salmon habitat. Though education is important to any recovery strategy, measuring results is more abstract than with other strategy components. Enumerating people reached through an educational program is one thing, but gauging how changing attitudes result in modified behaviors is quite another. However, as educational programs are implemented, public support for legislation, funding, and even recovery itself are expected to increase.

II. STILLAGUAMISH WATERSHED OVERVIEW

Characteristics of streams and rivers reflect variations in local geomorphology, climatic gradients, spatial and temporal scales of natural disturbances, and dynamic features of the riparian forest (Naiman et al. 1992). The freshwater and estuarine habitats of the Stillaguamish Watershed are the result of an integration of numerous physical processes that operate at many temporal and spatial scales. The channel reflects the combined effects of sediment, water, and large woody debris (LWD) supplied to the channel. In addition, channel morphology is constrained by valley form, riparian condition, and lithology. The delivery and routing of water, sediment, and woody debris to the stream channel are key processes in determining the ecological health of watersheds in the Pacific Northwest coastal region (Naiman et al. 1992). Human activities, which alter key processes, also influence the ecological health of watersheds.

The physical characteristics of the Stillaguamish Watershed are ultimately dependent on the geology, topography, watershed size, and climate, which operate on a long-term scale. These characteristics control landscape processes along with the range of possible habitat conditions in a watershed (Naiman et al. 1992). Landscape processes operate over a much shorter time frame and are often influenced by land management activities. These processes include hydrologic patterns; sediment supply and transport processes; water quality characteristics; and riparian forest conditions. Often modified by human activities, these landscape processes interact to determine the quality and quantity of habitats within the watershed.

A. PHYSICAL SETTING

The Stillaguamish River drains an area of approximately 181,303 ha (448,000 acres) and includes more than 7,432 km (4,618 miles) of streams and rivers (Figure 5). The river enters Puget Sound at Stanwood, 25 km (16 miles) north of Everett in northwest Snohomish County. Elevations in the watershed range from sea level to about 2,086 m (6,844 ft) on Whitehorse Mountain. The Stillaguamish Watershed can be divided into three general regions, the North and South Forks and the lower mainstem. The two forks join in Arlington, 17 river miles (28 km) from the mouth. The North Fork drains an area of 73,600 ha (181,866 acres). The South Fork is very similar in size draining 66,000 ha (163,086 acres), or 36% of the Stillaguamish Watershed. Drainage area percentages are provided for each region along with major tributary estimates (Table 1). Percentages for major tributaries also are included in the overall regional percentages.

Table 1. Stillaguamish Watershed drainage area percentages categorized by region and major tributary.

Region	Drainage Area
North Fork	41% (<i>Deer Creek 10% of total</i>)
South Fork	36% (<i>Canyon Creek 8% of total</i>)
Mainstem	23% (<i>Pilchuck Creek 11% of total</i>)

1. Climate

The climate is typically maritime with cool, wet winters and mild summers. Rainfall is highly variable throughout the watershed, average annual rainfall ranges from 76 cm/yr (30 in/yr) in the western portion of the watershed to 381 cm/yr (150 in/yr) at higher elevations in the eastern portion of the watershed (Pess et al. 1999). Approximately 75% of the precipitation falls between October and March. Precipitation and streamflows are highest in late autumn and winter as a result of rainstorms and rain-on-snow events. During the summer dry period, the lowest flows occur usually from July through September.

2. Geology

The geology of the Stillaguamish Watershed is described in Collins (1997). High grade Mid-Cretaceous to Paleocene melange rocks dominate west of the Darrington Fault. East of the fault, the primary rock type is Darrington Phyllite, a mechanically weak rock that dominates the upper North Fork Stillaguamish. Crystalline rocks of the Oligocene Squire Creek Stock form the south side of the North Fork and the north side of the upper South Fork Stillaguamish. Glacial outwash from the Puget Lobe of the Cordilleran ice sheet forms the fork terraces and topography of the lower watershed. Alluvial deposits are inset within the terraces and valleys of the lower watershed. The Stillaguamish mainstem flows through an alluvium-floored valley, 2 - 3 km (1 – 2 miles) wide, inset within terraces of glacial outwash.

3. Vegetation

Vegetation zones in the lower elevations of the Stillaguamish Watershed are characterized by western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii*), Sitka spruce (*Picea sitchensis*), and western red cedar (*Thuja plicata*). Deciduous species found in the lower elevations include, but are not limited to, red alder (*Alnus rubra*), black cottonwood (*Populus trichocarpa*), and bigleaf maple (*Acer macrophyllum*). Pacific silver fir (*Abies amabilis*) is found at the mid-elevations and sub-alpine fir (*Abies lasiocarpa*) is found at higher elevations (Franklin and Dyness 1973).

B. LANDSCAPE PROCESSES

In most watershed areas, the interaction of landscape processes control streamflow patterns; sediment supply and transport, input of allochthonous materials, channel stability, and the development and persistence of channel features utilized for spawning and rearing of chinook salmon. Allochthonous material is organic matter that is produced outside of the stream channel (e.g. leaf litter).

1. Significant Historical Events

Forest structure and landscape patterns changed considerably during the 1,000 years prior to European settlement, primarily due to the occurrence and patterns of large, stand-replacing fires occurring at intervals of 200 to 300 years. Peter (1999) assessed the upper Stillaguamish, within or adjacent to National Forest lands, and found that the upper basin has experienced several large, historic fires. Around 5,100 ha (12,602 acres) burned in the year 1000; while in 1300 and 1308, large fires burned over 28,300 ha (69,931 acres) across the upper watershed. In 1508, fires burned approximately 17,800 ha (43,984 acres) in the Texas Pond area, Canyon Creek area, and much of the upper South Fork Stillaguamish. Another large fire in 1701 burned over 16,600 ha (41,020 acres) primarily along the lower slopes of the upper river valley.

Due to this pattern of fire occurrence, large areas have historically been converted from older forests to early-seral forest in a matter of days. Fires in riparian areas remove vegetation cover and inputs of large woody material, and can result in increased erosion, loss of nutrients, and stream warming. Historical forest succession plays an important role in the current hydrological processes described below. Large fires occurred during much drier climates than exist today and set the stage for current forest conditions. From 1900 to the present, records show that only relatively small fires have burned, and were most likely associated with human activity.

Splash Dams were used in early logging operations throughout the upper Stillaguamish Watershed on both the North and South Forks of the River. Log crib dam construction on streams formed complete blockages to upstream migration of adult salmon and trout. Subsequent dam breaching caused complete destruction of riparian habitat and instream structure. Even though the last splash damming occurred in the early 1900s, there are effects that can be seen today. In addition, a log dam (approximately 12.2 m/40 ft vertical) remains on Black Creek that could eventually cause a mass wasting event.

2. Hydrologic Processes

Precipitation provides the primary source of surface and groundwater in the Stillaguamish Watershed. The quantity and route that rainfall and snowmelt runoff take before reaching the drainage network is dependent on topography, geology, and vegetation characteristics of the watershed. The alteration of these characteristics through land management can change the quantity and timing of runoff and streamflow. Precipitation may be intercepted by vegetation and subsequently evaporate, or it may reach the ground either directly or as throughfall. Once precipitation reaches the ground, it either evaporates; infiltrates the soil; flows overland until it reaches a stream or pond; or flows overland until it infiltrates. Water that infiltrates may be taken up by plants and transpired back into the atmosphere, stored in the soil, percolated through the soil to an aquifer, or flow through shallow subsurface layers into a stream. Each of these processes affects the amount and timing of streamflow (Spence et al. 1996). Landscape alterations disrupt these processes and change the quantity and timing of streamflow.

Depending on elevation, precipitation in the Stillaguamish Watershed may fall as rain, rain-on-snow (transient zone), or primarily as snow. The amount of watershed area that lies within the

transient zone is very important, because it is within the transient zone that rain-on-snow occurs. When rain-on-snow occurs in combination with runoff from rain, large floods may ensue. Rain-on-snow occurs when warm, moisture-laden air masses pass over snow, causing condensation of water on the snow surface; this process releases large amounts of latent energy, facilitating the rapid melting of substantial volumes of snow. Over one third of the Stillaguamish Watershed is in this rain-on-snow area (305 to 914 m or 1,001 to 2,999 ft in elevation).

Large floods are important in shaping stream channels and valley floors. Depending on size and channel orientation, the impacts of a flooding event vary. Steeper transport or headwater streams are usually modified only by larger floods, while alluvial and lower gradient reaches are modified by smaller, more frequent events. Flooding could both disturb the existing forest riparian corridors as well as create new landforms resulting from fluvial sediment deposition. Periodic flushing of sediment cleans gravel that is impacted by fine sediments, scours out sediments, or maintains pools for fish rearing and other life history requirements. Channel impacts from flooding events are influenced by the timing and magnitude of such events. Human activities can influence effects by altering riparian and upslope vegetation conditions and reducing wetland storage potential.

In contrast to flooding, droughts resulting from below-average precipitation and runoff can reduce the health of a forest ecosystem by weakening trees and making them more susceptible to insect and disease infestations. Instream habitat is reduced by low flows, and warmer water temperatures that can stress fish and create thermal migration barriers. Stillaguamish pink and chum salmon were impacted by drought conditions in 1979 and 1987 when reduced flows restricted access to the North Fork, causing much of the pink run to spawn in the South Fork, competing with chum for available habitat.

The amount of rainfall that eventually reaches groundwater and river channels is predominantly influenced by vegetation communities. Vegetation present on the landscape determines the amount of evapotranspiration that occurs. Evapotranspiration losses include water losses from interception and evaporation by vegetation; evaporation of water that reaches the soil; and water that enters the soil and is subsequently taken up by plants and transpired back to the atmosphere. The amount of water lost through these processes is dependent on the vegetation present, type of precipitation event (e.g. intensity, duration, and form of precipitation), and climatological conditions (e.g. humidity, wind speed, and direction). In the Northwest, total losses through evapotranspiration are generally highest for coniferous forest types.

In forested watersheds, most precipitation that reaches the forest floor infiltrates into the soil. Surface soils in old growth forests have high infiltration capacities due to high organic content and porosity (Spence et al. 1996). Subsequently, overland flow is uncommon and water typically enters streams by subsurface flow. As a result, the time of maximum streamflow usually lags behind peak rainfall events. The Puget Sound Lowland can be classified as a region that is dominated by a subsurface-saturated flow regime (Booth and Whipple 1991). In general, small headwater streams are more hydrologically dynamic than larger streams because runoff occurs more rapidly over steeper areas and because high intensity rainfall events are more common in smaller areas.

Land use disrupts these hydrologic processes by removing vegetation, which changes evapotranspiration rates, reduces infiltration to groundwater, and alters runoff processes by shifting flow patterns from shallow subsurface to surface. These landscape changes reduce baseflows to streams and increase the frequency and magnitude of peak flows. Collins (1997) used gauge data from the South Fork near Granite Falls and on the North Fork near Arlington to evaluate the historical pattern of peak flows within the Stillaguamish Watershed. He found that gauging records indicated a decadal-scale, cyclic pattern of peak flows within the Stillaguamish drainage.

Gauging records from the North Fork Stillaguamish show a systematic increase in peak flows over time. Ten of the largest eleven annual peak flows on record occurred between 1980 and 1995. The period of record Collins (1997) evaluated ran from 1928 to the present. Gauging records for Jim Creek and Pilchuck Creek also indicated a slight upward trend in peak flows for the periods of 1938-1957 and 1929-1976, respectively. These changes in peak flow frequencies have been attributed to forest practices such as clearcutting and road construction. Urbanization (Klein 1979; Booth and Jackson 1997) and agricultural activities (Hornbeck et al. 1970) also result in an increase in the magnitude and frequency of peak flows. Forest practices have a tendency, over the short term, to increase summer low flows, whereas urbanization and agricultural practices reduce summer low flows.

3. Sediment Supply and Transport

Sediment transported from upland areas and from within the channel determines the nature and quality of salmonid habitat in streams, rivers, and estuaries. The development and persistence of channel features used for spawning and rearing depends on the composition and rate that sediment is delivered (Spence et al. 1996). Sediment influx to channel networks is driven by rainstorms and other perturbations, which are discrete in time and space and occur over varied landscapes. For example, processes can occur in areas with unique spatial variability in topographical and colluvial properties, and various states of recovery from previous disturbances. Reeves et al. (1995) suggested that historically (prior to European settlement) in the Oregon Coast Range, periodic natural disturbances (sometimes associated with wildfires) served to replenish large woody debris (LWD) and coarse sediment in streams at intervals ranging from decades to several centuries or more. Following these disturbances, natural hydrologic processes would erode and redistribute the LWD and bed materials leading to a succession of habitat conditions for salmonids. By increasing the frequency of landscape disturbance and decreasing the quantity of LWD associated with the failures, land management has created a pattern of rapidly changing, simplified, poor quality habitats.

Sediment is delivered to stream channels by erosional processes such as mass wasting, surface erosion, and soil creep. In mountainous regions, mass soil movement is a dominant mechanism of sediment delivery and transport in stream channels (Swanson et al. 1987). The Stillaguamish Watershed is no exception, sediment loads within the watershed are predominantly generated by landslide or mass wasting activity (Figure 6). During 1997, a landslide inventory was completed on the Stillaguamish River. The inventory documented 1,080 landslides within the watershed

between the early 1940s and the early 1990s, of which 851 delivered sediment to stream channels (Perkins and Collins 1997). Sixty-one percent occurred in the North Fork basin, 36% in the South Fork, and only 3% in the lower basin. Seventy-five percent of the 1,080 landslides were associated directly or indirectly with human disturbance, most commonly clearcuts (52%) or road construction (22%). Individual, large deep-seated landslides account for a disproportionate amount of the sediment load. For example, the DeForest Creek landslide in Deer Creek doubled the sediment load in the entire Stillaguamish River system. Similarly, the Gold Basin slide was estimated to contribute up to 60% of the sediment from the upper South Fork. Turbidity levels may become elevated in all seasons as a result of large, persistent deep-seated landslides occurring in glacial lacustrine deposits.

In contrast to mass soil movement, surface erosion results from rain and overland flow gradually detaching and transporting materials downslope. Surface erosion commonly occurs on forestlands that have been disturbed by clearcutting or road construction. This process rarely occurs on undisturbed forestlands west of the Cascade crest because of high infiltration rates; although some erosion may occur in isolated instances in areas of steep ($> 27^\circ$) slopes (Swanson et al. 1987). Channelized erosion is the most common form of surface erosion on forestlands (Brown 1980), while sheet erosion is more common on low-gradient agricultural lands (Swanson et al. 1987). Both sheet and channelized erosion are common on lands being cleared for development. Vegetation cover tends to reduce sediment transport and detachment through the binding capacity of the root masses (Larson and Sidle 1981; Harvey et al. 1994), and can provide protection from detachment caused by rainfall.

4. Riparian Forest Conditions

The riparian forest performs a number of important functions that affect the quality and quantity of salmonid habitat. The health of aquatic systems is inextricably tied to the integrity of the riparian forest (Gregory et al. 1991; Naiman et al. 1992; Spence et al. 1996). Riparian vegetation provides shade, stabilizes stream banks, controls sediment, contributes LWD and other forms of organic matter, and regulates nutrient flux (FEMAT 1993; O’Laughlin and Belt 1994; Cederholm 1994; Spence et al. 1996). In addition, riparian vegetation provides a source of terrestrial insects, cover, attenuates flooding impacts, and provides a physical barrier to human disturbance. Scientists and land managers have widely recognized the importance of riparian forests. As a result, the establishment of riparian buffers often form the central element of aquatic habitat protection measures.

Riparian vegetation provides shade, which influences the amount of solar radiation that reaches stream surfaces and consequently moderates stream temperature on a daily and seasonal basis. Elevated stream temperatures affect salmonids in several ways including growth and development, life history patterns, disease, and competitive and predator-prey interactions. A Forest Ecosystem Management Assessment Team (FEMAT 1993) report stated that 100% of the potential shade value could be maintained by a buffer width equal to one site potential tree (SPT) height.

Riparian vegetation provides bank stability by increasing resistance to erosion. The vegetation root mass binds soil particles together providing a form of resistance to the erosional force of water. A diverse assemblage of vegetation types is thought to be more effective at maintaining bank stability and resisting erosion (Elmore 1992; Spence et al. 1996). Riparian vegetation may also facilitate bank building by providing areas of reduced water velocity during flood events, which in turn provides conditions that facilitate deposition. The FEMAT (1993) report suggested that the role of roots in maintaining bank stability is negligible at distances greater than 0.5 tree heights from the stream channel, under most conditions. Actively braiding or meandering stream channels may require a substantially greater width.

Standing riparian vegetation reduces streamflow velocity, providing conditions that promote the deposition of fine sediment. Downed LWD traps fine sediment as well as larger particles by creating a barrier. Riparian vegetation stabilizes banks from erosion and unstable areas that are prone to mass wasting. FEMAT (1993) recommended one SPT height as a buffer width to provide adequate sediment control. However, site conditions (e.g. soil type and slope steepness) may require considerably wider buffer widths.

Riparian zones contribute large quantities of small organic matter to stream systems. Small organic matter is an important food source for aquatic communities, although its importance decreases as stream order increases. Smaller streams are closed to solar radiation inputs and are in close contact with the riparian forest. In larger streams, which are more open to solar radiation, photosynthesis also becomes a source of food production, decreasing the importance of organic matter. In conifer dominated riparian zones, organic material (e.g. needles and cones) is delivered to the stream channel throughout the year, but is lower in quality and may take several years to be processed. In contrast, deciduous dominated riparian zones receive small organic matter during a 6 to 8 week period in the fall, which is processed quickly (Gregory et al. 1991; Naiman 1992). In westside stream channels, most organic material originates within the first 0.5 tree height (FEMAT 1993).

Riparian zones mediate the flow of nutrients to the stream and therefore are important regulators of stream production (Spence et al. 1996). Shallow, sub-surface flow from upland areas carries nutrients to the riparian zone where they are taken up by vegetation (Naiman et al. 1992) and released at a later date in an altered form. Lowerance et al. (1984) found that narrow riparian zones along stream channels in agricultural areas significantly affected stream chemistry. During flood events, nutrients from floodwaters may be captured by riparian vegetation (Cummins et al. 1994).

Trees within the riparian forest provide a source of LWD, a critical structural and biological component of stream systems, which influences the physical, biological, and chemical processes within streams. Large woody debris traps organic matter, influences sediment transport and storage, increases habitat diversity and quantity, creates substrate conditions for aquatic invertebrates, provides refuge for aquatic organisms, and moderates flow disturbance. Channel conditions such as gradient, sinuosity, width, and depth are often regulated by LWD (Nakamura and Swanson 1993). The greatest contribution of LWD to stream channels comes from trees that fall within one SPT height (FEMAT 1993).

C. BIOLOGICAL PROCESSES AND CONCEPTS

1. Life History Diversity

Understanding life history diversity is critical in the development of a chinook salmon recovery plan. Salmonid conservation strategies and enhancement measures should consider life history diversity (Carl and Healey 1984; Lichatowich et al. 1995). Habitat simplification through land use activities can effectively reduce the diversity of life history patterns. For example, historically the Yakima River had six life history types of spring chinook salmon, two of which reared in the lower mainstem of the Yakima River. The two lower river life history types no longer exist because of reduced river flows and increased water temperatures (Lichatowich et al. 1995). Changing habitat conditions also may have influenced life history patterns in the Stillaguamish Watershed. The life history type in the Stillaguamish is predominantly the ocean-type and a majority of adults return as three and four year olds. Chinook salmon that display ocean-type life history patterns usually spend only a few months in freshwater before migrating to sea. Stillaguamish chinook salmon historically had four life history patterns (similar to those documented in the Skagit River) with the age of spawning populations varying between two to six, or possibly seven-year-old chinook salmon. Currently, most Stillaguamish chinook display an ocean-type life history and reach maturity at three to four years of age.

A significant reduction in the quantity and quality of rearing habitat has been documented in the Stillaguamish. Approximately 70% of the side channel and slough habitat and 85% of historic estuary habitat has been lost (Pess et al. 1999). Both habitats are important to certain life history types. For example, stream-type chinook salmon rear in the river system for a year before migrating. During this period, they prefer areas along the margin of the river that provide cover such as off-channel and backwater habitat. Construction of dikes and levees along the mainstem of the Stillaguamish effectively eliminated much of the preferred habitat of the stream-type chinook. The loss of estuary habitat has also eliminated habitat required by the ocean-type chinook that prefers to reside in estuary habitats for a longer period. Harvest patterns (e.g. timing and gill net size) and hatchery practices (e.g. timing, size selection of brood stock collection, and outplanting of outside stocks) also may have contributed to a reduction in life history patterns.

2. Population Behavior

An understanding of spawning behavior is necessary for developing successful watershed-specific chinook salmon recovery strategies and determining the vulnerability of the population to extinction. Salmonid sub-population interaction is a key recovery strategy determinant. The interaction of sub-populations is described by the metapopulation theory, which describes the behavior of groups of populations that interact through straying or dispersal (Hanski and Gilpin 1991). Portions or sub-populations that are found in certain areas of a river system may go extinct, leaving habitats unpopulated that are later recolonized by straying. Levins (1969) describes a condition where a metapopulation is made up of sub-populations that have an equal probability of extinction. Therefore, in order for a population to persist, recolonization must

occur at an equal or greater rate to extinction. Harrison (1991) discusses a metapopulation model called *core-satellite model* that describes a metapopulation composed of a core population along with smaller satellite populations, which are maintained by dispersal or straying from the core population.

Of the two models, the second appears to be a better description of population dynamics in the Stillaguamish River:

- The core summer chinook spawning population occurs in the North Fork.
- Satellite populations occur in major tributaries and possibly in the South Fork.
- The core fall chinook spawning population occurs in the South Fork Stillaguamish with sub-populations or satellite populations in the mainstem.

The presence of satellite populations may be strongly dependent on habitat conditions and access to and condition of preferred habitats. For example, summer chinook salmon spawning in Squire Creek or Boulder River would constitute a satellite population whose strength in number from one year to the next may be limited by access to both (due to flow).

Three factors that play a role in the probability of local extinction are described in the literature. The probability of local extinction increases with decreasing population size, decreasing size of preferred habitat, and increasing isolation from other sub-populations (Hanski 1991). All factors are present in the decreasing summer and fall chinook salmon populations in the Stillaguamish River. Spatial shifts in the core spawning population have been documented in the North Fork Stillaguamish over the last 20 years (Pess and Benda 1994). Increases in sediment supply and annual peak flows affected the condition and quantity of spawning habitat. More frequent and lower base flow conditions resulted in more isolation and lower recolonization rates for chinook sub-populations. Beyond habitat destruction, Stillaguamish chinook salmon have a greater risk of extinction due to historical and natural fluctuations in the population.

3. Natural Predation

Chinook salmon are preyed on by a number of different species during different stages in their life history. Common piscine predators to salmon during their early freshwater life history periods include sculpin (*Cottus sp.*), bull trout (*Salvelinus confluentus*), dolly varden (*Salvelinus malma*), rainbow trout/steelhead (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarkii*), juvenile and yearling coho salmon (*Oncorhynchus kisutch*), juvenile and yearling chinook salmon, and northern squawfish (*Ptychocheilus oregonensis*). Avian predators of juveniles and smolts include Ring-billed Gulls (*Larus delawarensis*), Common Mergansers (*Mergus merganser*), Great Blue Herons (*Ardea herodias*), Double-crested Cormorants (*Phalacrocorax auritus*), Western Gulls (*Larus occidentalis*), Caspian Terns (*Sterna caspia*) and Belted Kingfishers (*Ceryle alcyon*). Mammalian predators including river otters (*Lontra canadensis*), bear (*Ursus sp.*), killer whales (*Orcinus orca*), harbor seals (*Phoca vitulina*), domestic dogs (*Canis familiaris*), and California sea lions (*Zalophus californianus californianus*) also prey on adult and immature salmon. Predation levels are much greater during early life history periods (e.g. egg, alevin, fry, and smolt life stages). Time spent in early life history stages is directly

related to predation rate. Habitat alterations that affect river flow, obstruct access, reduce cover, and increase water temperature often lead to increased predation rates.

4. Competition

Two types of competition are generally recognized (Moyle et al. 1986). *Interference* competition exists when one organism prevents a second organism from utilizing a resource through aggressive behavior. Competition through *exploitation* occurs when one organism is more efficient or effective at exploiting resources than a second organism. Both forms of competition can occur between individuals of the same species (intra-specific) and between species (inter-specific). Fausch (1988) has suggested that competitive interactions along with changes in habitat produce cumulative negative effects for coho salmon populations in some urban Puget Sound streams. Competitive interactions can be altered by changes in water quality, habitat, flow, food type and availability, and species composition.

In general, decreases in streamflow reduce available habitat and result in more intense inter specific and intra specific competition for rearing and spawning habitat, as well as for food resources. Introduction of non-native species and hatchery salmonids increases the potential for competition. Several warm water species, such as pumpkinseed (*Lepomis gibbosus*) and large mouth bass (*Micropterus salmoides*) have been observed in the Stillaguamish Watershed (Nelson et al. 1997). These species compete for space and food resources with stream-type juvenile chinook salmon. Increasing stream temperatures may give non-native, warm water species a competitive edge. Decreases in streamflow reduce access to spawning areas and intensify competition for accessible spawning habitat.

5. Disease

The role of disease within natural populations is poorly understood (Austin and Austin 1993). Salmonids are affected by a variety of bacterial, viral, fungal, and micro-parasitic pathogens. Serious disease problems in summer and fall chinook populations in the Stillaguamish Watershed have not yet been reported. However, isolated cases of unspawned, dead adult chinook salmon may be the result of disease. It is possible that high river temperatures (>16°C or >61°F) influence the immune system of chinook making them more susceptible to pathogens.

In several cases, river temperatures have been implicated for increased mortality rates in adult chinook salmon prior to spawning. The mortality rate of adult spawning chinook salmon in the Rogue River increased abruptly when temperatures started to exceed 20°C (68°F) (ODFW 1992). *Cytophaga* (formerly *Flexibacter*) *columnaris* was the presumed cause for the mortality. In the lower Elwha River, mortality of adult chinook salmon has occurred on a number of occasions. Warm water during late summer has been suggested as the cause for outbreaks of *Dermocystidium salmonis* in the lower Elwha River (NPS et al. 1994). The susceptibility of chinook salmon to disease may also be influenced by other factors such as low dissolved oxygen (DO), pollution, and population density (Spence et al. 1996).

6. Food

Energy available for growth and reproduction in freshwater ecosystems comes from two sources: 1) primary producers (e.g. macrophytes, benthic algae, and phytoplankton), which convert solar radiation to energy, and 2) organic matter from the riparian zone (e.g. leaf litter, small woody debris, and LWD). These energy sources are utilized by aquatic invertebrates that in turn are preyed on by salmonids. A change in these energy sources results in a change in the invertebrate community, and consequently the food base.

The river continuum concept (Vannote et al. 1980) describes the interrelationships of physical and biological processes along a river system. These relationships change in a systematic way along a river system as it flows from its headwaters to the ocean. For example, energy sources for aquatic communities found within the headwaters of the Stillaguamish River may be quite different from the energy sources and aquatic communities found within the mainstem of the Stillaguamish. In forested headwater streams, the primary source of energy (nutrients) is provided by allochthonous sources (e.g. leaf litter) from the riparian zone. In the mainstem Stillaguamish River, which is much wider and more open to solar radiation, nutrients from autochthonous sources (primary producers such as algae and macrophytes) usually contribute a greater proportion of energy to the system. Therefore, fish assemblages in the mainstem should be composed of a combination of species that feed on invertebrates, plankton, and fish (e.g. salmonids, dace, suckers, etc). In smaller headwater streams, invertebrate communities should be dominated by shredders and collectors, which graze on organic matter and the bacteria and fungi present on organic matter. Fish assemblages present are directly related to the types of invertebrate communities available.

Change in energy source can result in a shift in the aquatic invertebrate community and consequent fish assemblages. The food base in the lower Columbia has shifted from coarse detrital material derived from wetland vegetation and fine material derived from periphyton to a phytoplankton-derived food base. This shift in food base resulted in a change in invertebrate populations in the estuary from amphipods and isopods, the preferred items of salmonid smolts, to suspension feeding epibenthos, which are a preferred item of American shad (Simenstad et al. 1990). These documented shifts in energy sources are also possible in the Stillaguamish Watershed, where extensive diking has isolated much of the estuary and lower floodplains that historically provided the coarse detrital material used by invertebrates such as amphipods and isopods.

Features that increase channel roughness (e.g. log jams, boulders, and meander bends) influence the retention and processing of organic matter. Log jams retain sediments and trap organic matter (e.g. leaf litter, salmon carcasses), allowing for decomposition by bacteria and fungi and consumption by invertebrates. Nutrient retention is much higher in smaller streams than in larger rivers. However, rivers that have multiple channels or side channels and are allowed to flood have longer retention periods (Spence et al. 1996). Simplification of stream ecosystems will tend to make longitudinal patterns of retention more uniform and less efficient, thus lowering biological productivity. A simplified reach of river is typically one that is diked or ditched. The main reason for diking and ditching is to convey water, which runs counter to the need for retention.

7. Habitat Requirements of Chinook Salmon in Freshwater

Chinook salmon spend the earliest and latest life stages in freshwater river and stream habitats. While becoming sexually mature, chinook juveniles spend the majority of their time feeding in saltwater, then return to the river basins of their birth for reproduction. The freshwater requirements of chinook salmon are reasonably well known, although many subtle and important details of the freshwater life histories of specific stocks in the Stillaguamish Watershed remain unknown. Physical requirements for chinook salmon in freshwater can be divided into three broad categories: 1) pre-spawning adult migration; 2) spawning, incubation, and emergence; and 3) freshwater rearing and migration.

Juvenile chinook salmon are generally found in all mainstem areas, as well as larger tributaries. As chinook fry migrate, they usually inhabit marginal area, backwater habitat, and areas with bank cover (Healey 1991). Bjornn and Reiser (1991) found that chinook are attracted to stream reaches with large rocks that provide interstitial spaces for cover. Hayman et al. (1996) found that juvenile chinook salmon that rear in freshwater locations prefer backwater and natural bank habitat, compared to bar habitat and modified bank habitat (e.g. levees, rip-rap); side channels may also provide suitable rearing habitat.

Adult Migration Requirements

Environmental conditions required during adult upstream migration include adequate water quality, quantity, and cover. Adults migrating upstream must have streamflows that provide suitable water velocity and depth for successful passage. The amount of flow within a channel can determine whether chinook adults have access to areas within the river system traditionally used for spawning, as well as access to spawning beds. Low summer flows may limit access to spawning sites in tributaries such as Squire Creek or Pilchuck Creek. Migrating salmonids avoid waters with high silt loads or cease to migrate when such loads are unavoidable (Cordone and Kelley 1961); high turbidity may also delay migration (Bjornn and Reiser 1991). In addition, warm stream temperatures can lead to delays in migration and spawning as well as disease outbreaks. Hallock et al. (1970) reported delays in upstream migration of adult chinook due to high temperatures in their natal streams. They also observed that adult migration ceased when DO levels fell below 4.5 mg/l, and did not continue until DO levels exceeded 5 mg/l. Upon river entry, adult chinook seek out pools to hold in until spawning. The selection of active spawning sites has been theorized to occur near adult holding locations or areas of dense cover (Pess and Benda 1994). Proximity of cover to spawning areas may be a factor in the selection of spawning sites by some species of salmon (Bjornn and Reiser 1991).

Spawning Habitat Requirements

Substrate composition, cover, water quality, water quantity, and habitat area are important requirements for salmon before and during spawning. Healey (1991) suggested that fry and smolt production could be more related to the amount of good spawning gravel area than to the number of spawners. Chinook salmon primarily spawn in the main channel (North Fork Stillaguamish River) and larger tributaries (Squire Creek). Ranges in depth, velocity, and

substrate size preferred by chinook for spawning are very broad compared to other salmon species. Substrate sizes range from 1.3 to 10.2 cm (0.5 to 4.0 in) in diameter (Bell 1973), water velocity typically ranges from 0.46 to 0.91 m/sec (1.5 to 3.1 ft/sec), and a water depth of 46 cm (18 in) or more is common (Healey 1991). An additional requirement that is often overlooked is subsurface flow (Healey 1991), chinook eggs are large and more sensitive to reduced oxygen levels and therefore require substrate with adequate interstitial flow.

Body size may be an important factor in redd construction success (Healey and Heard 1984; Foote 1990). It has been hypothesized that larger individuals can excavate redds deeper and in larger substrate, obtaining added protection from scouring associated with flood events. Depth of egg burial has been reported to range from 10 to 80 cm (4 to 31 in) (Briggs 1953; Vronskiy 1972). Neilson and Banford (1983) reported that the average redd size for chinook was approximately 9.1 to 10.0 m² (98 to 108 ft²). Fecundity is highly variable in chinook within and between populations. The size of a female has been correlated to fecundity, but this can only explain 50% of the variation.

Incubation and Emergence Requirements

Flow, substrate condition, and redd depth appear to be important factors in incubation and emergence success. Important environmental factors during incubation include the level of fine sediment transported by the river and the frequency, duration, and magnitude of flood flows during incubation. More specifically, gravel size and percolation rate are two primary factors that influence the success of incubation and emergence. A percolation rate of 0.03 cm/sec resulted in a 97% survival rate, and a percolation rate of 0.06 cm/sec resulted in a survival rate of 84% (Healey 1991). Lethal temperatures during incubation include temperatures at or lower than 2.5° C (36.5 ° F) and temperatures that exceed 16° C (61 ° F). However, temperature has seldom been implicated for any significant egg loss during incubation.

Siltation in spawning beds can often lead to increased mortality (Shaw and Maga 1943; Wickett 1954; Shelton and Pollock 1966). Siltation that occurs early in the incubation period may have the greatest negative effect because during this period eggs are at their most vulnerable. Percent emergence decreases when fine sediments in the riverbed reach approximately 10 to 20% and mortality typically occurs from low DO levels or by entombment. Chinook salmon alevins have a difficult time emerging from gravel when the percentage of fine sediment exceeds 30 to 40% by volume (Bjornn 1968), including sediments 6.4 mm (0.25in) and less. Fine sediment in redds can also influence the size of emergent fry and timing of emergence (Koski 1966; MacCrimmon and Gots 1986). Gangmark and Broad (1955) and Gangmark and Bakkala (1960) showed that flooding was an important cause of chinook mortality in Mill Creek, California. Seiler (1996) found that higher flood flows in the Skagit River resulted in lower survival of chinook. In Fall Creek, California, Wales and Coots (1954) and Coots (1957) reported that approximately 68 to 93% of chinook mortality was associated with flooding.

Freshwater Rearing and Migration Requirements

On emergence from the redd, chinook salmon fry disburse, primarily at night. The rate of dispersal or migration is usually correlated with flow level. Lister and Walker (1966) as well as

Major and Mighell (1969), concluded that the amount of available rearing habitat limited the number of fry that remained in the area, with the rest migrating to available habitat. Lister and Walker (1966) also speculated that rearing habitat was a limiting factor in chinook smolt production in the Big Qualicum River. It is during this period that two life history patterns become differentiated, ocean-type and stream-type. Ocean-type chinook migrate to marine waters as subyearlings, while stream-type chinook remain in the river for one year and migrate as yearlings. Within the ocean-type life history pattern there are three subtypes: 1) chinook fry that leave immediately at 35 to 45 mm (1.4 to 1.8 in); 2) fry that migrate to marine waters from 2 to 6 months; and 3) fingerlings that migrate to marine waters in late summer or early fall. Based on beach seining and fyke trapping in the Snohomish estuary in 1986 and 1987, life history patterns in the Snohomish River system appear to be primarily the first two ocean subtypes and stream-type chinook (Beck & Associates 1986; Beauchamp et al. 1987). It also was suggested that the distance spawning occurs upstream may be a factor in freshwater residence time, and consequently the types of observed life history patterns.

Juvenile chinook salmon are principally found in all mainstem areas, including side channels and larger tributaries. As chinook fry migrate, they may inhabit the river's edge, backwater and off-channel habitats, side channels, or banks with cover (Healey 1991). Bjornn (1968) found chinook to be attracted to stream reaches with large rocks that provide interstitial spaces for cover. Hayman et al. (1996) found that juvenile chinook salmon rearing in freshwater locations in the Skagit River, preferred backwater and natural bank habitat, compared to bar habitat and modified bank habitat (e.g. levees, rip-rap).

Cover appears to be an important element in rearing habitat used by chinook salmon. Although cover is difficult to define, it can be defined as depth, turbulence, large substrate, overhanging vegetation, undercut banks, woody debris, floating debris, and aquatic vegetation. The number of juvenile chinook salmon remaining in pools increases with increasing amounts of cover (Bjornn and Reiser 1991). Brusven et al. (1986) found that 82% of age-0 chinook preferred stream sections with one-third overhead cover to sections without cover. The addition of cover increases the complexity of a space and its carrying capacity. Cover requirements vary seasonally and by size, therefore a complex mixture of cover types should be considered. In the Pacific Northwest, an important factor in complexity is LWD. Large woody debris creates both micro and macro habitat features, and is an important component throughout the drainage network from headwater streams to estuaries. In addition, LWD adds to substrate, velocity, depth heterogeneity, and provides cover.

Studies in Idaho suggest that substrate provides an important source of cover for chinook salmon. In summer, substrate contributes to a stream's carrying capacity by providing habitat for invertebrates, and perhaps less importantly, by providing cover (Bjornn and Reiser 1991). In contrast, during winter months substrate is more important as a source of cover than as a food source. Bjornn et al. (1977) found that the density of juvenile steelhead and chinook salmon in summer and winter was reduced by half when enough sand was added to fully embed the large cobble substrate.

In addition to substrate quality, the quantity and quality of pool habitat has been shown to be an important habitat element for chinook salmon. The abundance of age-0 chinook salmon in some infertile Idaho nursery streams appeared to be asymptotically related to the size of pool habitat (Bjornn and Reiser 1991). The number of juvenile chinook salmon increased linearly with increasing pool size, up to pools greater than 200 m² (2,153 ft²) in surface area. Pools greater than 200 m² (2,153 ft²) did not contain a higher number of chinook salmon. The effect of reducing space available to fish in small pools of third order streams was illustrated by Bjornn et al. (1977) in a stream sedimentation study. They reported that when sand was added to a natural pool, reducing pool volume by half and reducing the surface area of water deeper than 0.3 m (0.98ft) by two-thirds, fish numbers declined by approximately two-thirds.

The amount of food available to fish is another factor that determines a stream's carrying capacity. Production of aquatic invertebrates, a food source for juvenile salmon, depends on the amount of organic material available. Food preferences in riverine environments include adult and larval insects (e.g. chironomids), amphipods, and small fish. Food preferences of chinook juveniles include adult and larval insects that are typically part of the drift. The chinook diet is similar to coho, steelhead, and other stream dwelling salmonids (Mundie 1969; Chapman and Bjornn 1969). Chapman and Quistdorff (1938) found dipteran larvae, beetle larvae, stonefly nymphs, and leaf hoppers to be the most abundant food source in tributaries of the Columbia River. Becker (1973) found that insects constituted 95% of a chinook's diet during all seasons. Adult *Chironomidae* comprised 75 to 81% of their diet, *Trichoptera* adults comprised 3 to 5%, *Notonectidae* comprised 3 to 5%, and *Collembola* 1 to 5%.

Estuary Habitat Requirements

It is well known that estuaries provide important nursery habitat for ocean-type chinook salmon fry (Northcote 1976; Healey 1980, 1982). Levy and Northcote (1981) found that chinook salmon fry most often resided in estuary marsh habitats and tidal channels. Estuaries provide a physiological transition zone for adaptation to saltwater environments (Wedemeyer et al. 1980), an important forage location (Healey 1982; Simenstad et al. 1982), and cover for predator avoidance (Simenstad et al. 1982). Growth during river and estuary residence is critical to marine survival. Simenstad et al. (1990) speculated that total marine survival is determined by the availability of benthic and pelagic food sources during the juvenile outmigration period. Larger juveniles can exploit a wider variety of prey species and are less vulnerable to predation (Beauchamp et al. 1987). Most underyearling smolts from both Nitinat and Nanaimo Rivers are produced in the estuary rather than in the river (Healey 1982). The size and presence of chinook smolts captured during an outmigration study, conducted in Port Susan and the Snohomish estuary, suggest that local marine waters may also be important for growth. It has been hypothesized that mud and sandflats, between 0.03 and 1.98 m (0.10-6.50 ft), are the most productive intertidal areas for benthic invertebrates consumed by juvenile salmonids (Smith 1977). Important estuary habitats for chinook salmon include mud and sand flats, tidal sloughs, eelgrass beds, and shallow shoreline areas. The influence of LWD on these aquatic habitats is poorly understood; however, it is believed that LWD adds to substrate and depth heterogeneity and provides cover. In salt marshes LWD traps sediments, increasing the extent of the marsh. In mud flats, LWD further serves as a repository site for herring spawn (Spence et al. 1996).

Food preferences in estuarine environments include adult and larval insects, crustaceans, zooplankton, and small fish. Craddock et al. (1976) found zooplankton, especially *Cladocera*, to be important in the diet of chinook during July-August in the lower Columbia River. During a tagging feasibility study in the Stillaguamish, Kirby (1994) found that subyearling chinook salmon were actively feeding on bay shrimp larvae. Herrmann (1970) found that young chinook in the lower Chehalis River fed primarily on crustaceans, such as *Corophium*, and on adult and larval insects. Estuary feeding appears to be opportunistic (Healey 1991). In general, both adult and larval aquatic insects (e.g. *Daphnia*, amphipods, and *Neomysis*) have been identified as important food items (Kjelson et al. 1982; Healey 1991). Juvenile growth in estuaries is often superior to river-based growth (Rich 1920; Reimers 1971; Schluchter and Lichatowich 1977). However, juvenile growth may be disrupted in estuaries when “overgrazing” occurs, which is caused by large numbers of ocean-type chinook entering the estuary en-masse (Reimers 1973; Healey 1991), in addition large-scale hatchery releases may also result in overgrazing (Lichatowich and McIntyre 1987).

Residence time within the estuary appears to depend on juvenile chinook life history patterns. Ocean-type chinook fry and fingerlings reside in estuary habitat for a longer period of time than the stream-type chinook (Reimers 1973; Kjelson et al. 1982; Healey 1991). Stream-type chinook migrate quickly through the estuary, into near shore waters and to the ocean (Healey 1983, 1991). However, Beck and Associates (1986) found that yearling smolts entered the Snohomish estuary the second week of April and were found in low numbers for over two months. In the Snohomish estuary, subyearling chinook salmon were captured between early April through mid-July, peaking in May and June. Mark recoveries suggest chinook salmon juveniles reside in estuarine tidal channels for at least 1 to 10 days, and juveniles traveled up to 10 km (6 miles) throughout the sloughs over a period of 6 to 8 days (Beauchamp et al. 1987).

Habitat Linkages

It is generally believed that unconstrained, aggraded floodplain reaches were once highly productive habitats for some anadromous salmonids (Stanford and Ward 1992). In addition, off-channel areas adjacent to floodplains of larger rivers have been shown to be important rearing habitats for salmonids during high winter flood events (Tschaplinski and Hartman 1983). Fragmentation of habitat and the resulting isolation of populations may affect the long-term viability of salmonid stocks. In addressing habitat fragmentation and connectivity for the Northern Spotted Owl, Thomas et al. (1990) outlined several general principles that are equally applicable to salmonid recovery plans (Spence et al. 1996):

- Large blocks of habitat are preferable to small blocks.
- Patches of habitat that are close together are superior to those that are far apart.
- Contiguous blocks are preferable to fragmented habitats.
- Interconnected patches are better than isolated habitat patches, and corridors linking habitats function better when they resemble the preferred habitat of the target species.

Thus, the first objective of a salmon recovery plan should be to prevent further fragmentation of aquatic habitat. This should lead to the second objective; improve the connectivity between

isolated habitat patches. The third objective is to protect and restore areas surrounding critical refugia from further degradation allowing for the expansion of existing habitats such as:

- Preferred spawning areas.
- Off-channel floodplain habitat.
- Remaining estuary habitat.
- Complex sloughs and undisturbed blind tidal channels.
- Remaining natural riverbanks.

III. STATUS OF THE CHINOOK SALMON POPULATION

A. HISTORIC POPULATION STATUS

1. Estimating Population Size

An important component of developing a salmon recovery plan is to estimate the historic populations of salmon within the watershed prior to extensive land use changes. Historic estimates provide reference points to compare with current population trends. A number of methods were used to obtain historic population estimates. Previous researchers and the current review team developed some of these methods. When evaluating the Washington Department Fish and Wildlife (WDFW) historic escapement and production estimates, it is important to remember that these estimates are based on limited or incomplete spawner surveys prior to 1965 (Ames pers. comm. 1999). Comprehensive escapement methodologies using the current method did not begin until 1977 (Hendricks pers. comm. 1999). Furthermore, estimates of natural escapement may have been influenced by unmarked hatchery outplant returns being counted as natural spawners.

WDFW Index Method I

The first estimate of historic chinook production and escapement was quantified by WDFW mid-1960s and completed in 1970 as part of the *Puget Sound and Adjacent Waters Report* (PSTF 1970). Chinook production was estimated by using redd and fish counts in key spawning index areas from 1956 to 1965. Index counts were then expanded to estimate chinook habitat within the basin. The assumptions used for this methodology are unknown. For comparison, estimates from the Skagit Watershed were also included.

Natural chinook escapement for the Stillaguamish Watershed from 1956 to 1965 was 160 to 10,880 fish, with an average of 4,940 (Table 2). On the Skagit/Samish, natural chinook escapement ranged from 10,360 to 40,690 with an average of 19,190 fish. The average total production (escapement plus harvest) for the Stillaguamish was 19,760 chinook and 76,760 chinook for the Skagit/Samish. Peak total production for the Stillaguamish was 43,520 and 162,760 adult chinook for the Skagit watershed.

WDFW Index Method II

In 1976, Ames and Phinney of WDF developed the second production estimate as part of the *Washington Streams and Salmon Utilization Catalog* (Ames and Phinney 1977). This method was similar to the one used in the Puget Sound and Adjacent Waters Report and involved counting redds in an index area and expanding those numbers based on usable habitat within the watershed. The time period for this production estimate was from 1966 to 1971. Chinook escapement estimates for the Stillaguamish ranged from a low of 4,000 to a high of 9,700, with an average of 7,000 fish returning to the river to spawn (Table 2). Estimated peak total

production for the basin was greater than 30,000 chinook from 1966 to 1971; this estimate was based on harvest expansion factors.

Escapement Ratio and Land Ratio Methods

Several approaches may be used to estimate historic chinook production. Each approach requires the historic 1935 Skagit River terminal catch record, 51,748 chinook (WDF 1975), and applies the 1956-65 ratio of Stillaguamish/Skagit escapement numbers and watershed areas to the terminal catch record. The escapement ratio method results in an estimated terminal area run size of 13,321 chinook. The watershed area ratio method results in an estimated terminal run size of 11,733 chinook. It was assumed that the ratio of habitat area was similar for the 1935 and 1956-65 periods, that chinook in both watersheds use similar habitat types, and that survival rates are comparable between watersheds and time periods.

Coded Wire Tag Method

The coded wire tag (CWT) method was used in the most current data collection effort. Beginning in 1986, a portion of the Stillaguamish chinook smolt output was wire tag coded for a U.S./Canada Indicator Stock Study. CWT recoveries during the 1986-1991 period show a total production of between 1,200 to 4,550 chinook (Table 2) with an average of 2,875. Natural escapement during the parent brood years ranged from a low of 400 in 1983 to a high of 1,409 in 1985 (Rawson pers. comm. 1999). The above method is compared to a pre-development (1870) estimate that was completed for the Nisqually River.

The Nisqually Watershed (184,100 ha or 454,929 acres) is similar in drainage area to the Stillaguamish (177,400 ha or 438,373 acres). The method also relies on an extensive habitat utilization model and reach-by-reach assessments based on the professional judgment of local watershed biologists. The habitat model estimated a predevelopment escapement of approximately 13,000 chinook and a current capacity for only 1,500 fish (Nisqually EDT Workgroup 1999 Draft). These numbers are similar to the historic and current estimates of chinook escapement for the Stillaguamish Watershed (Table 2).

Table 2. Summary for historic Stillaguamish chinook salmon estimates.

Method Name	Research Year	Escapement Range	Peak Escapement	Production Range	Peak Production
WDFW Method 1	1956-1965	160-10,880	10,880	640-43,520	43,520
WDFW Method 2	1966-1971	4,000-9,700	9,700	30,000	30,000
Escapement Ratio	1935/Escp Ratio	13,321	13,321	N/A	N/A
Land Ratio	1935/Land Ratio	11,733	11,733	N/A	N/A
CWT	1986-1991	400-1550	1,550	1,200-4,550	4,550

Gresh et al. 2000

2. Chinook Salmon Stock Characteristics

Spring Chinook Salmon

Spring chinook can potentially be found in the upper reaches of the watershed where colder water temperatures are common. In addition, they often are associated with steelhead habitat and are found above pink salmon habitat and below char habitat. In general, there is a spatial and temporal separation between spring, summer, and fall chinook stocks (Kraemer pers. comm. 1998). Currently within the Stillaguamish Watershed, there are few areas that meet the habitat requirements for spring chinook.

Biological information is limited on the historical life history variations for Stillaguamish chinook salmon. In reviewing historical scientific information for the watershed, very few references were found for observations of spring chinook. The 1921 Skagit and Stillaguamish Rivers Biological Survey Report (Smith and Anderson 1921) states that very few spring chinook were seen in Boulder River. Similarly, the 1952 Washington Department of Fisheries (WDF) Puget Sound Investigations Progress Report noted that 11 spring chinook were documented spawning in August in the North Fork Stillaguamish, which was the first observation of spring chinook in the North Fork Stillaguamish since 1922.

Reviewing historical catch records for Port Susan from 1949 to 1978, small numbers (<100) of returning adult chinook were consistently caught during the month of June (during most years) up to the mid 1970s. In 1958, 197 chinook were caught between May 20 and May 31, this was the only year on record with chinook captures in May. Typically, returning adult spring chinook enter the rivers in April and May and hold in pools prior to spawning in the fall. Historic references of spring chinook in the Stillaguamish Watershed may be complicated by the release of hatchery spring chinook during the early 1950s and by subjective definitions of when spring chinook timing occurred. Observations of early fish in the Port Susan fishery and spawning in the North Fork Stillaguamish could indicate a distinct stock, or those fish could have been part of an earlier portion of the existing summer run chinook currently spawning in the North Fork.

Summer Chinook Salmon

Summer run chinook is the predominant chinook stock within the Stillaguamish Watershed. On average, 60 to 80 % of the chinook production for the watershed is believed to be summer chinook (PFMC 1997). These fish typically begin returning to the river in June, with the last fish spawning by the end of September. The majority (80%) of the summer chinook spawn in the middle and upper sections of the North Fork Stillaguamish, with limited numbers of fish using the larger tributaries (Boulder, Squire, and French) for spawning.

Pess and Benda (1994) documented a strong association between pool habitat and spawning location. Areas of the river that have usable spawning habitat, but no pool habitat have very limited spawning. Approximately 44% of all chinook spawning occurs within 35 m (115 ft) of a pool, even though pool spacing averages one every 300 m (984 ft). Pess et al. (1999) documented a 38% loss of pool habitat in the North Fork since 1950.

Summer chinook select spawning areas that are associated with tail outs, riffles, and bars in the deeper portions of the low flow channel area. These spawning locations put their redds at high risk for impacts from late fall and winter flooding. Summer chinook females typically lay 3,000 to 5,000 eggs in one or more nests. Nests are generally located in gravel 3 to 8 cm (1 to 3 in) in diameter, and eggs usually are buried in gravel up to 25 cm (10 in) deep.

Eggs require, on average, 480 temperature units to reach the eyed stage and 900 temperature units to hatch. In the Stillaguamish River, chinook eggs should reach the eyed stage from late September through mid-October and should hatch from late October through mid-November. Emergence from the gravel usually occurs during December and January.

Outmigrant data collected from coho smolt traps indicate that some chinook fry move up into smaller tributaries (Grant, Fortson, McGovern, and Hazel Ponds) during the winter to avoid flooding impacts and to forage for food (Nelson et al. 1987).

Outmigrant studies have documented smolt migration beginning as early as March 10 and ending as late as the June 14. In one outmigration study, smolt size ranged from 58 mm to 83 mm (2.29-3.27 in). A review of existing data for both outmigrant trap studies and adult scale analyses, indicate that there are a very limited number of wild, outmigrant chinook leaving the system as yearlings. These yearling outmigrants typically make up 4 to 9% of the fish leaving and returning to the system (Seiler et al. 1984).

A portion of the outmigrant chinook population rears in the Puget Sound and contributes to the winter blackmouth fishery. Recent research by Beamish et al. (1998) documented outmigrant chinook rearing in Puget Sound (through at least September) feeding on fish, crab larva, and euphausiids. Based on CWT recoveries, the majority of Stillaguamish summer chinook migrate north off the coast of Canada and then return back, at maturation (three to five years), along the same route.

Department of Fish and Wildlife catch records from 1949 to 1978 indicate that greater than 75% of the chinook caught in Port Susan were caught by mid-September. This information further supports the idea that the vast majority of chinook production in the Stillaguamish has been summer run fish rather than fall chinook. Returning fall chinook typically enter the estuary and river later in the season.

Fall Chinook Salmon

The few small populations of fall chinook located in the Stillaguamish Watershed can be found in Jim Creek, Pilchuck Creek, and the lower portion of the South Fork Stillaguamish. Fall chinook also are infrequently found in French Creek and Canyon Creek.

Fall chinook tend to enter the river later than spring and summer chinook, with fish arriving on the spawning grounds during mid-September and completing their spawning by mid-October. Fall chinook are more likely to use the larger tributaries and lower portions of the main river for spawning areas. Incubation typically occurs from mid-September through late January in gravel

ranging in size from 3 to 8 cm (1 to 3 in) in diameter. In general, fall chinook prefer to lay their eggs in areas of subsurface upwelling, along the bars and tail outs of pools.

There are several possible explanations as to why there is limited fall chinook production in the Stillaguamish. Fall chinook are more likely to use larger tributaries in the watershed, which are prone to lower flows and warmer temperatures during the fall chinook return period; this can lead to physical and thermal blocks to migration. In addition, many of the larger tributaries have experienced considerable habitat degradation. There have been major sediment inputs, which have increased fine sediments, streambed instability, pool habitat loss, and warmer water temperatures.

Another possible impact on native fall chinook runs could be from extensive outplanting of hatchery fall chinook from other watersheds. From 1956 to 1973, more than nine million fall chinook fingerlings and fry from outside the watershed were planted into the North and South Fork Stillaguamish (WDF 1993). These outplanted fish may have interbred with resident fall chinook, reducing the genetic fitness of the local population.

3. Historic Size and Age Distribution

Size and age distribution information can be readily determined for Stillaguamish chinook based on recoveries of CWTs in various fisheries, as well as spawner surveys. This analysis showed that age 2 chinook averaged 485 mm (19 in) fork length, age 3 – 675 mm (27 in), age 4 – 849 mm (33 in), and age 5 – 965 mm (38 in) (Figure 7).

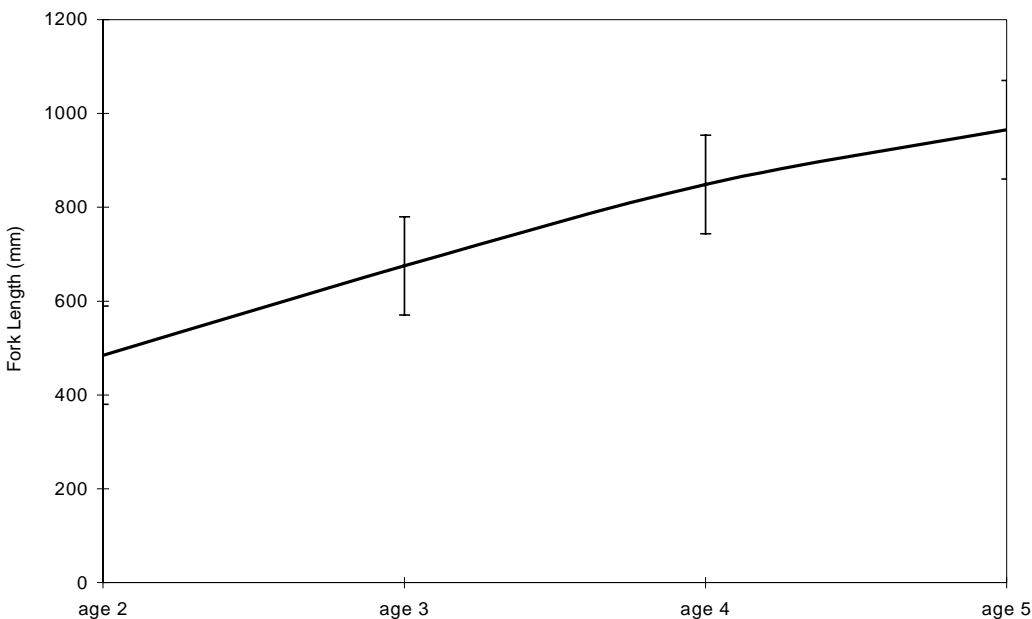


Figure 7. Stillaguamish origin chinook salmon average size (with error bars) at age 2-5 for brood years 1980-1991.

Analysis of age at time of fishery carcass sampling showed that the age of spawning chinook was typically 3 to 4 years, with the majority at age 3. Age of Stillaguamish origin spawning chinook was also 3 to 4 years, but the majority were at age 4 (Figure 8).

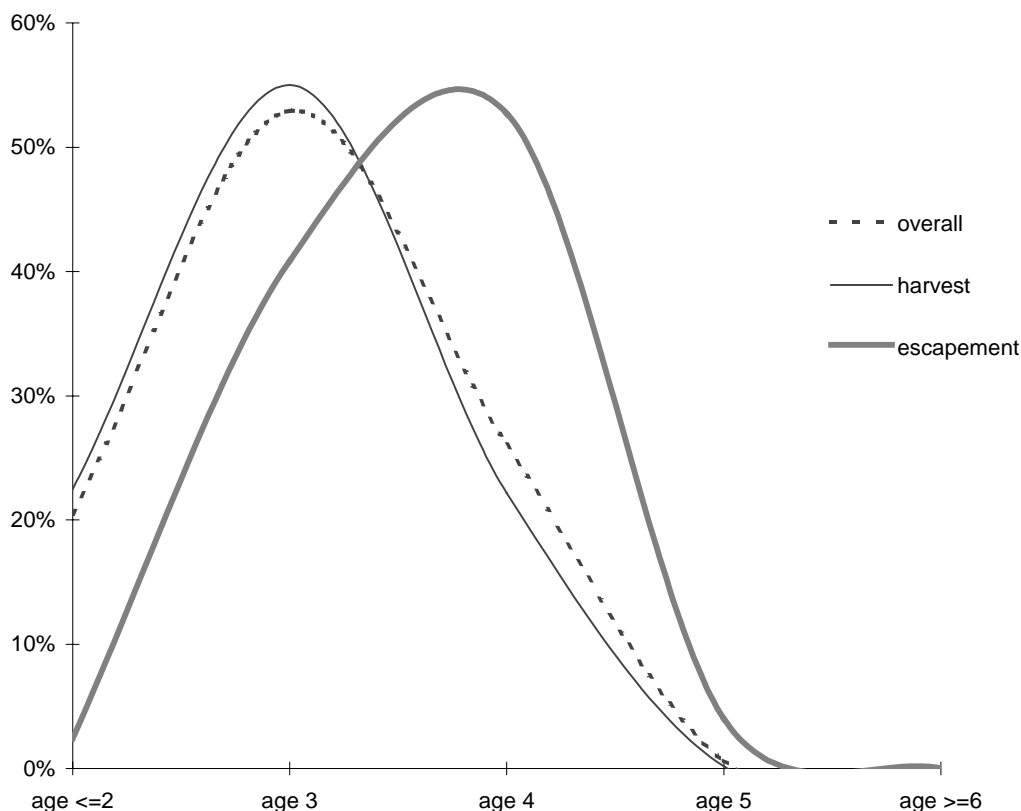


Figure 8. Stillaguamish origin chinook salmon average age at sampling (1980-1993).

4. Historic Role of Artificial Production

Prior to the onset of the Stillaguamish Tribe's Natural Stock Restoration Program, the WDF planted chinook into the Stillaguamish from other watersheds dating back to 1952 and continued to outplant outside stocks until 1974 (Appendix A).

These outplant events were initiated for several reasons. Chinook salmon plants in the upper South Fork served to establish a run of fish into newly accessible habitat, created by the construction of the Granite Falls Fishway. Chinook also were released to mitigate habitat degradation and to provide additional fishing opportunities.

The Stillaguamish Tribe began the chinook program in 1980 in response to their analysis that the pre-terminal harvest rate was too high. The excessive pre-terminal harvest rate restricted river tribal fishermen from catching their allocation, and forced them to make conservation closures to protect what returning spawners remained.

The early chinook releases (1980-1984) from the tribal enhancement effort were scatter planted throughout the basin, totaling between 90,000 to 125,000 fish ranging in size from 400 fish per pound to 160 fish per pound (Appendix B).

In the fall of 1983 the DeForest Creek landslide began, depositing more than 1 million cubic yards of sand, silt, and clay into Deer Creek and the North Fork and mainstem of the Stillaguamish River (Deer Creek Report 1984). This sediment input significantly decreased the quality and quantity of spawning and rearing habitat for chinook below the mouth of Deer Creek, by reducing pool habitat and increasing stream bed movement (Pess and Benda 1994). In addition to the DeForest Creek Slide, there were a series of major landslides during the late 1960s and early 1980s in the upper portions of the North and South Fork Stillaguamish, which significantly degraded chinook habitat in the middle and upper sections (Pess and Benda 1994).

Based on previous concerns about excessive pre-terminal harvest and considerable habitat degradation, the Stillaguamish Tribe made the decision to expand the Chinook Natural Stock Restoration Program. Simultaneously, the Chinook Technical Committee of the Pacific Salmon Commission (PSC) identified Stillaguamish chinook as a stock of immediate conservation concern.

In 1987, the United States and Canada selected the Stillaguamish chinook as a wild indicator stock species for study. The Stillaguamish Tribe's hatchery at Harvey Creek was then renovated and expanded to accommodate the production of 250,000 wild origin chinook smolts, each marked with a coded wire tag.

In addition, the WDF implemented a watershed planning process for salmon recovery in the Stillaguamish Watershed. The result was a draft Stillaguamish Native Chinook Recovery Plan (Stillaguamish Tribe of Indians 1987), which included recommendations to: 1) continue North Fork production at 200,000 wild origin smolts annually, and 2) establish a program to re-seed under-utilized habitat in the South Fork Stillaguamish. Excess North Fork chinook was the chosen stock for this phase of the rebuilding plan. Major improvements to the Granite Falls Fishway also were recommended.

The focus of the expanded North Fork Stillaguamish Recovery Program was to get chinook adults from the enhancement effort to return to historic spawning grounds, rather than returning to a hatchery rack. The first few years of plants occurred off the Whitehorse Bridge (river mile 35), but after consultations with WDF enhancement staff, the tribal enhancement biologist modified the program to allow a 3-week acclimation period at the Fortson Mill Pond to improved homing back to the historic spawning grounds.

Beginning in 1990, a cooperative program was developed with WDFW, which allowed chinook presmolts to be transferred and acclimated at the WDFW steelhead hatchery at Whitehorse. This was a superior site to the Fortson Mill Pond location because it provided a better water source and around the clock monitoring by Whitehorse Hatchery staff. The hatchery location also was located in the peak spawning area for wild chinook.

In the spring of 1992, the Stillaguamish Tribe began reseeding the South Fork Stillaguamish with North Fork fish. A temporary net pen was installed at the mouth of Beaver Creek in the upper South Fork and 25,710 fish were released in May. There were additional outplantings in 1994 (185,940) and 1995 (75,900).

Recent genetic research by WDFW on the South Fork Stillaguamish chinook below Granite Falls has shown this small population of fish to be genetically distinct from the North Fork Stillaguamish chinook (Busack and Shaklee 1995). This information, in conjunction with concerns about potential hybridization of the two stocks, resulted in discontinuing the Upper South Fork planting of North Fork Stillaguamish chinook after the 1995 release.

5. Historic Fishery Impacts/Harvest

From the 1977 brood year through the 1991 brood year, exploitation rates¹ (ERs) in the Stillaguamish summer/fall chinook salmon management unit are estimated to have declined steadily from approximately 70% to approximately 50% (PSC 1998). The absolute ER estimated by the PSC model include a high level of uncertainty because factors such as incomplete assessment of CWT fish escapement and differential harvest rates on different sizes, ages, and sexes are not considered in the model². However, the trend is clear despite a gauntlet of mixed-stock fisheries operating, in some cases, for several years on the same brood of chinook; managers have been successful in achieving harvest rate reductions.

It is likely that ERs have declined further for subsequent brood years due to both preterminal and terminal area restrictions on fishing implemented in 1997. Retention of chinook salmon is not currently allowed in recreational fisheries in the Stillaguamish/Port Susan terminal area (including the river and nearby marine waters), except in specific locations and times when hatchery-produced fish can be targeted with minimal impact on wild chinook salmon. In the Stillaguamish/Port Susan terminal area the commercial net fishery directed at wild chinook salmon has not been opened since 1984. Incidental harvest in net fisheries directed at other species or harvestable hatchery fish is carefully monitored and planned so that total impact rates will stay below guideline levels. Despite the ER reductions, spawning escapements have not improved appreciably due to concurrent declines in marine survival and freshwater productivity (PFMC 1997).

Based on CWT recoveries between 1986 and 1990, the harvest distribution for Stillaguamish River chinook production was the following: Canadian fisheries caught 41%, United States mainland 37.6%, Alaska 4%, and 21% of the chinook were escapement back to the river. During the 1990-1994 period, the Alaskan catch was 9%, Canadian 41%, United States mainland 17%,

¹ This is a so-called “AEQ” exploitation rate, computed from the model used by the Pacific Salmon Commission’s chinook technical committee. It measures all sources of fishing-induced mortality (including both retention and non-retention mortality) as $(R-E)/R$, where R is the total number of fish that would have returned to spawn naturally in the absence of fishing and E is the estimated natural spawning escapement.

² The models should be revised to reflect the rates of exploitation on older fish and on females to better assess the fisheries’ success in getting numbers of eggs on the spawning grounds.

and escapement 33%. Chinook mortality due to harvest can be assigned to two primary activities: 1) recreational harvest and 2) commercial harvest. These impacts can be further delineated based on the geographic location where mortality occurs.

In general, all harvest related mortality takes place in Alaska, British Columbia (BC), or Washington State (Figure 9). Alaska's harvest is primarily commercial, while the harvest of Stillaguamish origin chinook in BC and Washington is primarily recreational; however, there is a considerable commercial component typically as bycatch during other fisheries such as sockeye and coho. Poaching numbers are unknown.

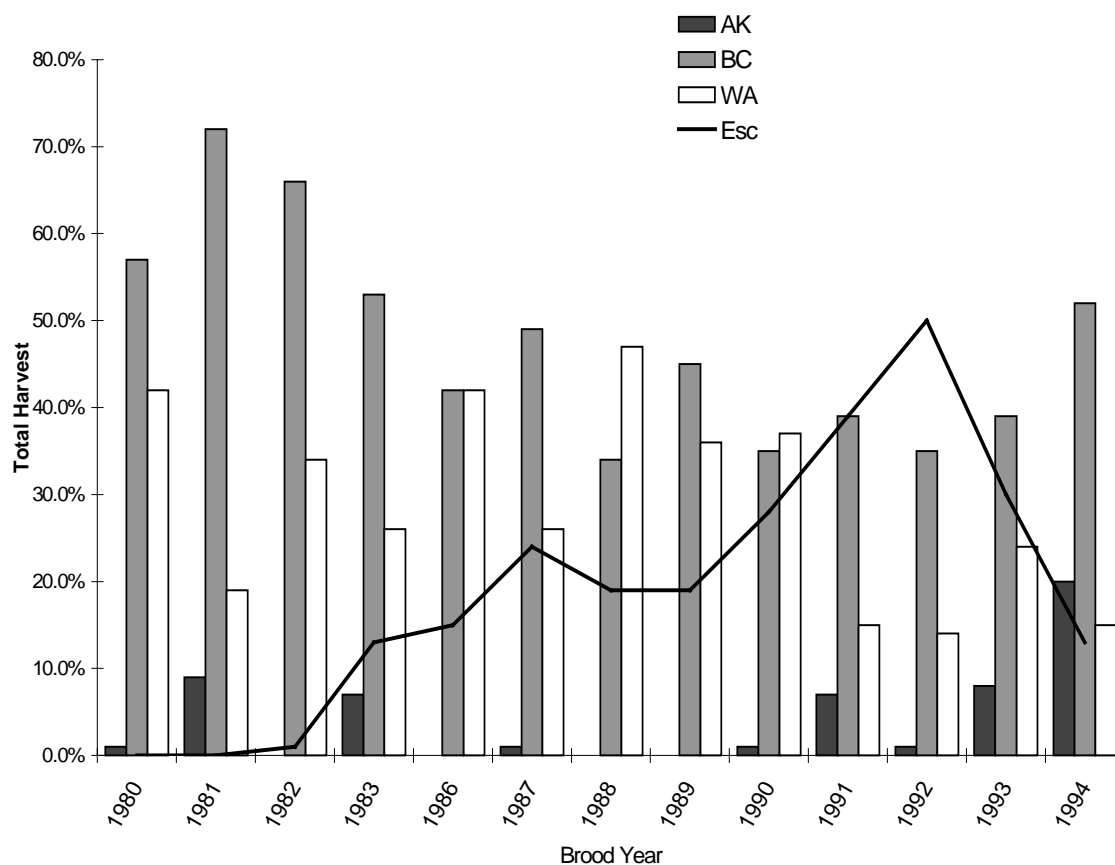


Figure 9. Stillaguamish origin chinook salmon harvest distribution by brood year (based on CWT recoveries).

B. CURRENT POPULATION STATUS

1. Population Size (Total Recruitment and Spawning Population)

In the past, total recruitment has been difficult to determine due to limited CWT harvest information from commercial fisheries, limited recreational harvest information, and uncertainties with spawning escapement estimations. The implementation of a US/Canada

Indicator Stock Program on North Fork Stillaguamish summer chinook and increasing tag numbers and recoveries have begun to improve estimations of total recruitment. Total recruitment (hatchery + wild) estimates during the 1986-1993 period ranged from 1,239 to 2,981 for North Fork chinook (Rawson pers. comm. 1999).

Uncertainties with different spawning estimations are currently being resolved by increasing the number of surveys, and incorporating total redd counts, redd life measurements, and fish per redd. In addition, ongoing studies with a complete census of chinook redds may allow for comparisons of the relative accuracy of the various methods.

2. Current Population Characteristics

Stillaguamish chinook are divided into two distinct stocks (WDF 1993), a summer stock and a fall stock (represented together in Figure 10). This division was based on spawning time and differences in geographical distribution. The Stillaguamish chinook have been managed for natural production with a combined escapement goal of 2,000 adults for the two stocks.

Summer Stock

The summer stock generally comprises about 85% of the total Stillaguamish Watershed chinook escapement. Status of this population was classified as “Depressed” in the 1993 Salmon and Steelhead Stock Inventory effort. The escapement goal for the basin has not been met since 1976. In addition, escapements since 1993 have not shown significant improvement, especially when the escapement of naturally produced fish is examined independently. It appears that in spite of the ongoing supplementation effort, the population is only holding stable. It is too early to tell with any certainty if the recent (1998 and 1999) reduction in fishing rates will lead to increased escapements.

Fall Stock

Origin of the Stillaguamish fall chinook is unknown; confounded by the regular releases of “Green River type” fall chinook from the late 1950s to the early 1970s. In the last 25 years, there have been no releases except those from the Stillaguamish tribal facility, which has generally supplied North Fork summer stock. The fall stock population generally accounts for about 15% of the basin’s escapement. The status of this population is also classified as “Depressed” based on consistently low escapements (WDF 1993).

Spring Stock

Spring Stock chinook populations exist in the North Puget Sound region and may be found in the Stillaguamish Watershed. Currently, there are no documented spring chinook populations in the basin, although occasional early redds have been seen in Canyon Creek, an area of reported possible spring chinook use. It is unclear whether the fish reported in the river during the spring of the year were true spring chinook or just the first of the entering summer chinook. However, anecdotal reports indicate that spring chinook may have been present historically in the Stillaguamish Watershed. At present, there is little habitat in the watershed that could be

classified as typical spring chinook habitat, except possibly the upper reaches of Canyon Creek and South Fork above Granite falls, an area above historical anadromous fish use.

Genetic Diversity

In terms of genetic diversity, salmon populations are typically divided into three hierarchical categories. The first is called *stock*, which is defined as a group of interbreeding individuals that is genetically distinct and essentially reproductively isolated from other such groups. Stocks typically exhibit similar life histories and occupy ecologically, geographically, and geologically similar habitats. The next level of hierarchy is the *genetic diversity unit (GDU)*, which is defined as a group of genetically similar stocks that is genetically distinct from other such groups; a GDU may consist of a single stock. The final and broadest category is *major ancestral lineage (MAL)*, which is defined as a group of one or more genetic diversity units whose shared genetic characteristics suggest a distant common ancestry, and substantial reproductive isolation from other MALs. Some of these categories are likely the result of colonization and diversification preceding the last period of glaciation (Busack and Shaklee 1995).

The Stillaguamish chinook salmon, which is thought to consist of two stocks, is part of the larger Puget Sound MAL. This MAL consists of 5 GDUs: South Sound summer/falls, South Sound spring, North Sound summer/fall, South Fork Nooksack spring, and North Fork Nooksack spring. The Stillaguamish chinook are on the cusp between the two summer/fall GDUs in the MAL. Recent data indicate that the Stillaguamish fall chinook genetically align most closely with the South Sound chinook, which includes such stocks as the Green River Falls and the Snohomish summer and fall stocks. It is unknown whether this relationship is the result of past planting practices or is a reflection of historical relationships.

The Stillaguamish summer stock genetic background is not similar to the fall stock, instead it aligns genetically with the North Sound summer/fall GDU. The Stillaguamish summer stock is similar to the Skagit summer stock. This is not surprising given the connection (geologically indicated) between the Skagit and Stillaguamish Basins via the Sauk River in recent geological times.

3. Current Role of Artificial Production

Description of Current Projects

The current North Fork Stillaguamish Chinook Restoration Plan has tribal staff capturing 65 male and 65 female adults returning to the spawning grounds during August and September. Brood stocking occurs at multiple locations distributed above Deer Creek in the historic spawning area of the North Fork. Chinook are captured using a small mesh gill net, which is drifted down through holding pools. Both adipose-clipped and non-clipped fish are captured and retained. Fish are held in capture pens in the river and then transferred to tank trucks for hauling to the hatchery, where they are ponded until ready for spawning. On arrival at the hatchery, female chinook are vaccinated to prevent the transfer of bacterial kidney disease to the offspring and are placed in separate, covered circular tanks until ready to spawn. When spawning occurs, gametes from adipose-clipped and non-clipped fish are kept in individual, color coded

containers. Prior to 1997, in order to address genetic concerns about small numbers of fish over representing the total population, multiple crosses were made only between marked and unmarked fish.

Five non-clipped females will have their eggs pooled and then re-divided into individual buckets, with each bucket fertilized by a different adipose or non-adipose clipped male. When adipose-clipped females are fertilized, only non-clipped males are used. This fertilization process helps to expand the genetic diversity of the spawning population and reduces the concerns about crossing only hatchery origin, adipose-clipped fish. Beginning in 1997, due to the large percentage of adipose-clipped hatchery fish in the brood stock population, hatchery staff implemented random spawning of adipose and natural adult chinook. During the spawning process, a fish pathologist from the Northwest Indian Fish Commission sampled all spawned fish, and hatchery staff collected pertinent biological information on spawned fish such as weight, length, fecundity, CWT, and age structure.

Eggs are rinsed with baking soda to increase fertilization success and then disinfected with an iodine compound to reduce disease transfer to the offspring. Finally, the eggs are incubated in vertical incubation trays on pathogen free well water.

Young fry are transferred out of the incubators to early rearing troughs, which also contain pathogen free well water, and are reared for approximately 30 to 45 days before being transferred to large outdoor circular tanks. The water supply for these tanks is surface water from Harvey Creek. Harvey Creek has several runs of salmon and trout, which access the watershed above the hatchery intake.

In early April, all fish are coded wire tagged and then transferred to the WDFW hatchery at Whitehorse for a one-month acclimation prior to release. A pathologist then checks the fish prior to release and the fish are released at a size and time that approximates the in-river chinook smolt outmigration. Information collected from the outmigrant trap studies within the watershed has shown that peak outmigration occurs during mid- May and the chinook are in the 70 to 90 fish per pound range.

Contribution of Artificial Production Fish to Natural Spawning

Initial analysis of CWT data and escapement data (Scott pers. comm. 1999) indicated that between 1994 and 1996, the natural stock restoration program fish made up between 27 to 56% of the spawning escapement for the North Fork Stillaguamish, and between 18 to 38% of the total spawning escapement into the watershed. Between 1991 and 1993, program fish contributed between 5 to 90% of the North Fork escapement and between 4 to 62% of the total escapement to the watershed. The considerable variation in contribution rates during the 1991-1993 period may be accounted for by an extensive drought and flooding period that occurred during the 1987 to 1990 parent years.

IV. FACTORS AFFECTING THE POPULATION

A. FRESHWATER AND ESTUARINE HABITAT MANAGEMENT

1. Population and Land Use

Background

Prior to European settlement, many Native American tribes utilized the Stillaguamish Valley; particularly from Barlow Pass down to the river's mouth near Stanwood. Europeans first settled in the lower basin in the early 1860s and began diking and draining the floodplain for agricultural purposes shortly thereafter. Removal of log jams allowed areas upriver to be cleared and settled, facilitating access to the upper reaches and giving rise to several small towns.

Logging began in the lower river as early as 1863 and was hastened by the establishment of timber mills near Florence and Silvana. As upriver navigation and access improved, logging became more widespread, reaching into the upper river and its tributaries. By the turn of the century, nearly all of the floodplain land on the mainstem had been cleared of trees and converted to agricultural lands. Accompanying this was the large scale conversion of tidal-influenced salt marsh habitat to agricultural lands through diking, ditching, and filling (Collins 1997). By 1900, the population of Snohomish County had already grown to 24,000 people. Expanding population and historic land use practices have all resulted in broad landscape alteration.

Current Population and Land Use

Basin-wide land cover within the Stillaguamish Watershed is 76% forestry, 17% rural, 5% agriculture, and 2% urban (Figure 11). However, streamside land use within the hydrological-connected area utilized by anadromous fish (the anadromous zone) is comprised of 61% forestry, 22% rural, 15% agriculture, and 2% urban (Pess et al. 1999).

Forestry: Federal, state, and private forest land uses occupy the majority of the watershed. Current use of forest lands have two relevant considerations for salmon restoration planning. First, timber harvest activities in steep headwaters have and continue to cause channel widening and significant sediment loads in tributaries of the North and South Fork Stillaguamish River. An analysis of 1,080 landslides within the Stillaguamish Watershed reveals that 74% were associated with clearcuts and roads (Collins 1997). Landslides in glacial sediments are deep-seated and a chronic source of turbidity and suspended sediments in all seasons. Second, in conjunction with forestry, road building is a significant contributor to cumulative sediment loads. Designs to mitigate toe erosion with engineered log jams is the focus of ongoing restoration feasibility work for some of the larger landslides (Hazel, Gold Basin, DeForest, and Canyon Creek). Landslide hazard zone mapping has been proposed as a tool to minimize sediment loading basin-wide (Collins 1997).

Agriculture: Farming is the most prevalent land use in the lower floodplain. Agricultural land uses relate to fish recovery in the context of livestock management, drainage infrastructure, and riparian/wetland area management. Without proper ditch maintenance practices and nutrient management, water quality can be impaired by both nutrients and sediment. Protection, restoration, and management of riparian areas and wetlands within the lower floodplain are essential to salmon recovery. In many cases, such critical areas have been converted to agricultural lands and are actively farmed. Many potentially productive sloughs and side channels have become isolated from the main channel on or near farms. Proposals to reconnect Koch and Thompson Sloughs to the mainstem are potentially positive steps in the process of chinook salmon recovery.

Existing dikes and revetments were installed to protect agricultural land from floods and tidal influences, however they limit chinook productivity (Figure 12). Such structures directly reduce habitat productivity by restricting meander and floodplain processes that maintain and restore habitats. Salt marsh habitat for juvenile salmonids is severely limited near tidal channels as a result (approximately 1.5% of the historical area remains). Although much of this habitat alteration occurred decades ago, the dikes continue to prevent recovery due to isolation of important rearing habitat.

Urban/Rural: Currently, Snohomish County has a human population of nearly 600,000 and is growing at an annual rate of 2.5%. Being more rural and distant from major economic centers, the Stillaguamish Watershed accounts for approximately 6.5% of the total county population and is experiencing a slower growth rate. In 1999, the population of the Stillaguamish Watershed reached an estimated 32,912 (Snohomish County 1999). Continued population growth will place increasing pressure on local natural resources through the residential development of forest and agricultural lands.

Historically, forest and agricultural land management practices have been the primary source of most habitat loss in the Stillaguamish Watershed. However, the conversion of existing forest and agricultural lands to rural residential uses has also been identified as a leading cause of declining salmon stocks in the watershed. Impervious surface, created by such development, impairs habitat function by reducing the area available for infiltration and increasing surface runoff (Spence et al. 1996). Urbanization negatively affects water quality through lawn fertilizer and pesticide inputs, household and municipal sewage discharges, industrial sources, and contaminated runoff from roads. Development activities in urbanizing areas also frequently result in stream channelization and bank hardening, further impairing habitat function and hydrology.

Future Growth Management

Growth management allows cities such as Arlington and Stanwood to expand within their urban growth areas. Managed growth is intended to exploit existing urban infrastructure, however it also affects surrounding areas as satellite residential and commercial development takes place. In Addition, rural residential land use tends to erode habitat function in a patchwork manner and presents recovery challenges in sub-basins such as Portage and Church Creek. Commercial

development, in conjunction with growth, has created extensive habitat disturbances, toxic point source pollution, and large-scale increases in impervious surfaces.

The Growth Management Act (GMA), adopted by the Washington State Legislature in 1990, was developed to address population growth and urban sprawl in rapidly urbanizing areas of Washington State. Consequently, Snohomish County and the cities of Arlington, Granite Falls, and Stanwood are all subject to the provisions of the GMA. For this reason, each local government has prepared or revised a comprehensive plan that projects future growth and ensures consistency of urban infrastructure (e.g. transportation, capital facilities, and utilities) through extensive zoning and land use planning. Under the GMA mandate, creation of Urban Growth Areas (UGAs) is intended to restrict high density development to urban areas where such infrastructure already exists. As a result, comprehensive plans aim to protect rural and critical areas, reduce sprawl, and maintain productive agricultural and timberlands from adjacent development. Comprehensive planning may adopt development regulations that result in localized impacts upon some critical areas, but in no case should such impacts result in a net loss of the value and function of such ecosystems within a watershed.

GMA requires local governments to address land use concerns beyond the scope of the State Environmental Policy Act (SEPA), which often results in case by case “afterthought” planning for fish and wildlife. This legislation provides for a comprehensive view of the entire landscape prior to development plans and lessens the cumulative impacts allowed for by SEPA. In addition, the legislation requires interjurisdictional coordination in developing planning policies, which will help such policies to be consistent throughout the home ranges of fish and wildlife. Three of the 13 stated goals outlined by the legislature when developing the GMA can be directly related to fish and wildlife resources:

1. Maintain and enhance natural resource-based industries, including productive timber, agricultural, and fisheries industries. Encourage the conservation of productive forestlands and productive agricultural lands, and discourage incompatible uses;
2. Encourage the retention of open space and development of recreational opportunities, conserve fish and wildlife habitat, increase access to natural resource lands and water, and develop parks; and
3. Protect the environment and enhance the State’s high quality of life, including air and water quality, and availability of water.

Such intended benefits of GMA policies may be curbed by the actual implementation of land use regulations. For example in rural areas, new GMA density limits will not be effective in areas where higher density lot patterns have already been established. Also, development interests are presently able to use docketing requests and appeal to the hearing examiner to have land use designations changed and housing densities increased. Planned residential developments (PRD) under GMA are designed to encourage the preservation of open areas where development is taking place; however, when open space is used for sports facilities or urban parks, properly functioning habitat necessary for salmon recovery is lost. Less habitat protection may be

achieved if increased development densities are exchanged for poor open space quality in conjunction with a PRD. Mixing high and low density land uses can deter watershed based planning and restoration efforts in sub-basins and critical areas. Consistency in development regulations and enforcement will continue to be a major salmon recovery issue.

Impervious Surface and Stormwater

Research indicates that stream quality impairment is correlated to the percentage of watershed imperviousness (Booth and Reinelt 1993; NMFS 1996a; Spence et al. 1996; Booth and Jackson 1997; May et al. 1997; Horner and May 1998). Stream hydrology, morphology, water quality, and ecology are all negatively impacted as permeable soils are compacted and/or covered by structures, concrete, and asphalt. Stormwater runoff from impervious surfaces such as rooftops, roads, and parking lots may well pose the most serious threat to salmon recovery by negatively impacting channel stability, biodiversity, and water quality. These direct effects of growth and development are a critical factor limiting chinook recovery in the Stillaguamish Watershed, given overall pressures and the continuing challenges of growth management near critical areas.

Impervious surface densities resulting from even low development densities produce stream habitat characteristics that do not support salmonids. Total impervious area (TIA) is a combination of areas that have had their infiltration capacity reduced through anthropogenic activities plus areas that naturally contribute to surface water. Schueler (1995) noted that as TIA increases, channel stability is first affected, followed by biodiversity and water quality in the order listed. Ironically, water quality, which is the last parameter to be affected, is the measure most commonly used to assess and monitor the effects of urbanization on stream systems.

A GIS analysis of Puget Sound Regional Synthesis Model (PRISM) land cover classes illustrates TIA by sub-basin (Figure 13). This analysis uses 28.5 m² pixel resolution data, derived from August 1998 Landsat imagery, to assign impervious area percentages for the Stillaguamish Watershed. Impervious land cover classes include high density developed, rural and urban light developed as well as shallow and open water. High density developed land includes residential industrial and commercial lands (e.g. tennis courts, sidewalks, roads/road base, concrete, and asphalt).

In the Puget Sound lowland region, Horner and May (1998) suggested that the steepest rates of decline in biological function occur as TIA increases above 5%. Similarly, other researchers have shown that noticeable impairment of water quality, decreases in macroinvertebrate and fish diversity, degradation of fish habitat, and declines in fish abundance occur at levels of imperviousness as low as 7-12% and become severe above 30% (Spence et al. 1996). Interestingly, 0.40 ha (1 acre) residential use zoning results in an average of 10% TIA while 0.20 ha (0.5 acre) residential zoning results in an average of 20% TIA (Schueler 1995).

More than one third of the sub-basins within the Stillaguamish Watershed, have a TIA exceeding 13% and have stream conditions that may not be properly functioning from an impervious area perspective (Table 3). Arlington City and Stanwood City, the most urbanized sub-basins in the Stillaguamish, predictably have the highest TIA at 76% and 66% respectively. Several of the remaining sub-basins with higher levels of impervious area are also associated with the lower

mainstem watershed. In addition to degradation of stream hydrology, habitat, and water quality within these sub-basins, these impacted streams exert cumulative effects on the lower mainstem to the detriment of chinook salmon and other species.

Of the remaining streams, eight are considered “at risk,” while twelve have a TIA of 6% or less with properly functioning stream conditions. Many of these sub-basins continue to urbanize with TIA increasing at slow to moderate rates. For other sub-basins on state and federal forestlands, urbanization is less of a threat. However, past and present forest practices also alter proper stream function by creating impervious surfaces and compacted soils on logging roads and landings, and reducing infiltration rates by removing vegetation cover.

Table 3. Total Impervious Area (TIA) and habitat performance category for sub-basins in the Stillaguamish Watershed.

TIA	TIA Performance Category	Sub-basins
1 - 6%	Properly Functioning	Jim Creek, Frailey Mountain, Hell-Hazel, Boulder Ridge, Robe Valley, Canyon Creek, Higgins Ridge, Upper South Fork, Deer Creek, Upper North Fork, Gold Basin, Grandview Area
7 - 12%	At Risk	Squire Creek, Ebey Hill, Stillaguamish Canyon, , Silvana Terrace, Hat Slough South, Prestiens Bluff, Pilchuck Creek
13 - 30%	Not Properly Functioning	Jordan Road, Jackson Gulch, Burn Hill Road, Tributary 30, Kackman Road, Arnot Road, Arlington Junction North, Church Creek, Arlington Junction South, Portage Creek, Stillaguamish Floodplain
Greater than 30%	Severe Impairment	Arlington City, Stanwood City

Compliance with federal and state laws has major implications for the management of our water resources during the next decade. Snohomish County and other jurisdictions within the Stillaguamish Watershed must develop (or revise) and implement policies to ensure compliance with these regulations. For example the CWA requires states to set standards for pollution and to enforce violations. The goals of the Act are to have “swimmable and fishable” waters where people can safely swim and water quality does not threaten the health of fish, shellfish, and wildlife.

Municipalities and enterprises operating under a National Pollutant Discharge Elimination System (NPDES) permit from the Environmental Protection Agency will undoubtedly be required to include more stringent conditions for development and increased protection of aquatic resources when these permits are renewed. At the same time, the Washington

Department of Ecology (WDOE) has begun to develop a cleanup plan (e.g. Maximum Daily Loads or TMDLs) for the Stillaguamish Watershed. The purpose of this plan is to identify pollution problems and implement specific Best Management Practices (BMPs) to control nonpoint pollution. These mandates are also driven by increasing number of CWA violations, which go hand in hand with continued commercial and recreational shellfish harvest restrictions and closures. Such restrictions, directly linked to human and animal waste-related contamination, have affected every recreational and commercial shellfish harvest area in Snohomish County (DOH 1998).

Snohomish County Code Titles 17 and 24 regulate construction and drainage activities to ensure that their effects on natural drainage patterns on or adjacent to the project site are minimized or mitigated. This regulatory approach is intended to ensure that water quantity and quality, sedimentation, control of stormwater runoff, aquatic habitats, and wetlands are all considered. These, and other local laws will require continuous updates under an adaptive management approach to chinook recovery.

Small catchments and sub-watersheds are particularly vulnerable to increasing impervious surface, especially when wetland complexes have been removed. Wetland preservation and regeneration are perhaps the strongest tools to mitigate impervious surface and support habitat characteristics. Overall, watershed-based planning including water treatment, sensitive area protection, riparian buffer networks, development activity guidelines, site designs, and monitoring can provide a comprehensive approach to managing growth impacts. Special attention must be paid to maintaining the functioning catchment and managing conversion of rural properties to suburban densities. A watershed planning scale approach, along with protection and acquisition of large tracts of undeveloped land, will be key in minimizing and mitigating the effects of increased impervious surface area.

2. Factors Contributing to Decline and Limiting Recovery

Estuarine Salt Marsh and Tidal Channel Loss

Blind tidal channels in salt marshes provide habitat for several species of juvenile salmonids, including chinook salmon (Levy and Northcote 1982). Fry and fingerling chinook salmon make extensive use of estuarine habitats (Rich 1920; Congelton et al. 1981). Fry generally enter the estuary in March and April and remain until June, while fingerlings arrive in May and June and remain until August or later (Healy 1991). Growth is relatively rapid in these rich feeding areas, with observed growth rates ranging from 0.39-56 mm/day (0.02-2.21 in) in the Fraser River estuary, to 0.53-86 mm/day (.02-3.39 in) in the Sacramento-San Joaquin estuary (Levy and Northcote 1981).

Prior to European settlement (circa 1870), there were approximately 1,800 ha (4,448 acres) of salt marsh habitat connected to the Stillaguamish Watershed. Roughly one-third of this was in Skagit Bay, contiguous with the Stillaguamish River tributaries. Greater than one-third was on the delta and south of Hat Slough and the remainder was on the island defined by Davis slough, West Pass, and South Pass. By 1886, a considerable amount of marsh had been diked, and only one-third of the original salt marsh remained. By 1968, only 15% of the original salt marsh

remained, with a concomitant loss in blind tidal channels. During the period from 1886 to 1968, approximately 400 ha (988 acres) of material was accreted into Port Susan and Skagit Bay, but the newly accreted salt marsh does not have the same well-developed channel system and does not provide the same habitat quality (Collins 1997).

Riparian and Upland Clearing

Holding habitat in the form of deep, cool pools ($<16^{\circ}\text{C}$ or $<61^{\circ}\text{F}$) with abundant LWD, is a vital habitat element for chinook because they spend a long time in freshwater before spawning. The pools provide low velocity areas with overhead cover (depth and LWD), allowing fish to conserve energy reserves while sexually maturing, and to avoid harassment by humans and other predators. Pools adjacent to spawning areas also provide resting habitat and predator protection during spawning. Cool water temperatures typically reduce vulnerability to aquatic disease and parasites.

In the Stillaguamish Watershed, the potential for pools to act as long term holding areas for chinook and other species is rated poor in all mainstem segments, due to the lack of cover throughout the mainstem and the amount of pool filling observed since 1986 (Stevenson pers. comm. 1994; Hazel Watershed Analysis 1996). These observations are supported by research that has documented recent, large magnitude changes in channel morphology in the mainstem North Fork Stillaguamish (Pess and Benda 1994).

An intact riparian system is essential for providing low temperatures, LWD, and reducing sediment that results in channel aggradation and pool filling. Currently, a considerable portion of the Stillaguamish Watershed is either degraded or severely degraded (Pollock 1998); (Figure 14). From 1870 to 1910, riparian logging had removed most, if not all, large conifers on the mainstem, lower South Fork, and North Fork up to Rollins Creek (Collins 1997). A decade later, riparian forests in nearly all of Church Creek, much of Pilchuck Creek, lower portions of the North Fork Tributaries, and the South Fork Valley up to Granite Falls had been logged. By the 1940s, most riparian areas in the anadromous zone had been logged, with the exception of upper and middle Deer Creek and uppermost Jim and Canyon Creeks. Much of this land was converted to agricultural and urban uses, and consequently little replanting occurred.

At the turn of the century, deciduous trees dominated the floodplain accounting for 63% of individual tree species; primarily red alder, black cottonwood, and big leaf maple. In the uplands, 79% of the forest was dominated by coniferous species, primarily western hemlock, Douglas fir, Pacific silver fir, and western red cedar. Currently, 52% of the riparian areas in the Stillaguamish Watershed are dominated by hardwoods, small conifers, or no trees at all. Large conifers make up 21% of the riparian forest, while 14% is composed of medium sized conifers. The remaining 13% is mixed hardwood and conifer of medium size (Pollock 1997). Less than 1% of intact conifer riparian forests occur on non-federal land.

Logging activities have also led to increased landslide rate and volume. An inventory of 1,080 landslides in the Stillaguamish Watershed, documents widespread sliding during the period of aerial photographic record (1933-1996). Three-quarters of the slides are associated strictly with

timber harvest and road building in steep headwaters, 52% clearcutting, and 22% with road construction.

An inventory of tributary channels that have undergone widening, noticeable on aerial photographs, indicates that landsliding and riparian logging caused widespread widening and aggradation in tributaries. Geomorphic and temporal concentrations of landsliding or unusually large landslides, caused large scale increases of sediment supply in the North Fork, which affected salmonid spawning and rearing (Pess and Benda 1994). Increased sediment loads from logging also presumably accelerated sedimentation in the mainstem and estuary (Collins 1997).

In the freshwater environment, the quality (gravel size and fine sediment composition) and stability of chinook salmon spawning habitat are key factors affecting chinook production. Generally, the egg-to-fry survival decreases as the amount of small particles in the gravel increases (Bjornn and Reiser 1991). Smaller sediments reduce inter-gravel water flow, which limits life-sustaining DO and interrupts removal of metabolic waste. Fine sediment accumulations in the spawning gravel can also prevent fry from emerging from the gravel, entombing them in the streambed. Substrate ranging from 1.3 to 10.2 cm (0.5 to 4.0 in) is considered appropriate spawning gravel for chinook (Bell 1973). Fine sediment (<0.85 mm or <0.034 in) concentrations greater than 11% can cause a significant reduction in egg-to-fry survival for salmonids. Levels at or below 11% are often encountered in relatively pristine habitats (Peterson et al. 1992).

Land Use Related Hydrologic/Geomorphic Alterations

Peak flow records (1929-1980) indicate similar decadal-scale recurrence of major peak flow events in all parts of the Stillaguamish River. This indicates a regional-scale climatic driver to the recurrence of considerable peak flow events. These events occur largely in the period of mid-November through February and can be related to both rainfall only and rain-on-snow precipitation.

Gauge data from the North Fork show a systematic increase in annual peak flow discharge superimposed on the decadal-scale peak flow pattern. Ninety percent of the largest annual peak flows on record occurred between 1980 and 1995. Although the South Fork exhibits the same decadal-scale pattern of peak flows, there is no similar pattern of increasingly larger annual peak flow as in the North Fork. Peak flow responses are strongly related to the timing and extent of timber harvest on private, state, and federal lands along with the other factors discussed in this section (Jones and Grant 1996a, b; Pollock 1997).

a) Floodplain Reclamation

Reclamation of tidelands, constricted channels, cut-off sloughs, and increased delta progradation has considerably reduced the quantity and quality of salmonid rearing habitat. Two-thirds of the existing reclamation occurred between 1870 and 1886. Historical removal of log-raft jams has destabilized channel banks and degraded the channel bed by increasing stream gradients and velocities; this also led to the release of large quantities of stored sediment, and eventually resulted in the creation of “hanging” sloughs. Main channel bed degradation exacerbates the

disconnection of channel and floodplain. The majority of log jams were removed on the Stillaguamish River between 1877 and 1893 (Collins 1997).

Flood control activities dominated from 1930 to present and precipitated the loss of more than one-third of the channel area from 1933 through 1991. Channelization, bank protection, levee and dike construction, railroad grade construction, and channel filling shorten and narrow channels within the floodplain. These alterations increase water velocity and, for the same discharge, may lead to increased flooding. These protective measures also decrease the area that could potentially receive floodwaters, increasing the cumulative potential for catastrophic floods downstream. Bank revetments are another important feature in the watershed. United States Army Corps of Engineers' records from 1955 to 1965 show over 53 km (33 miles) of rip-rap armoring basin wide, with the majority of structures present on the mainstem.

b) Mining

Aggregate mining has reduced channel aggradation by 75% west of Interstate 5 (I-5), and has resulted in net degradation in the mainstem from I-5 east to Arlington reach. Recent off-take figures indicate that from 1986 to 1991, an average of 135 kcy/yr of material was mined in the entire mainstem reach. This is a 150% increase over the 1962-1985 average of 54 kcy/yr. The total off-take from 1962 to 1991 was 2.1 million cubic yards.

Had this off-take not occurred, a deposition of an average of 27 kcy/yr downstream of I-5 and an average of 37 kcy/yr in the I-5 to Arlington reach would have occurred. This is important in channel geometry terms, because net volumetric change in the same period based on channel cross-sections was + 9 kcy/yr downstream of I-5 and - 28 kcy/yr in I-5 to Arlington reach. A wide and shallow channel results in high summer stream temperatures and lower DO levels. The Stillaguamish River is listed as an impaired waterbody for both temperature and DO, among other parameters, on Washington's draft 1998 Clean Water Act (CWA) 303(d) list.

Mining off-take contributes to the disconnection of the floodplain from the main channel and side-channel sloughs. The groundwater table may be lowered, potentially reducing summer baseflows in and reducing recharge to side channels and sloughs. Stream bank and bed stability reductions can also increase sediment delivery downstream. Overall mining reduces the potential for restoration and maintenance of floodplain (riverine and palustrine) wetlands.

Loss of Wetland/Beaver Pond Habitat

The relationships between wetlands and chinook production are based on both direct and indirect functional characteristics. The most obvious direct example is use of estuarine wetlands by chinook during different life stages. Estuarine areas are used for rearing, staging, and smoltification. Most outmigration rearing occurs in the freshwater areas of estuarine marshes until the juveniles smoltify. Juvenile fish move from the fringe of the marsh at high tide to the tidal channels at low tide (Groot and Margolis 1991). The use of these fringe areas in the estuary suggests that stream-type chinook may seek similar habitat structure in rivers with greater productivity and cover throughout their freshwater rearing phase.

A recent report entitled *The Current and Historical Influence of Beaver on Coho Smolt Production in the Stillaguamish River Basin* (Pollock and Pess 1998) provides information on the historical presence of beaver ponds and their associated functions. The research states that beaver pond habitat within the anadromous zone of the Stillaguamish Watershed (the area currently available to coho) has been reduced by 81 to 96% from historic levels. This is a decrease from an estimated historic area of between 200 to 1,200 ha (494-2,965 acres) down to the current estimated area of 40 ha (988 acres). Historically, beaver ponds accounted for between 34 to 72% of the total coho smolt production in the Stillaguamish Watershed, if production was summer rearing habitat limited, and 65 to 90% of the total coho smolt production, if production was winter rearing habitat limited (Pollock and Pess 1998).

A WDOE (1990) study compiled existing data on hydric soils and wetland inventories to compare existing wetlands to historic wetland areas. A comparison of potential and existing wetland areas, as well as subsequent loss is presented for the Stillaguamish Watershed (Table 4). This analysis provided a list of potential restoration sites. Restoration activity is naturally contingent on property owners current or future land use plans. The existing total wetland area was estimated to be 2,500 ha (6,178 acres); (Figure 15). Based on wetland soils, there were historically 11,800 ha (29,158 acres) of wetlands, indicating that an estimated 78.5% of the historical wetlands have been degraded or lost.

Table 4. Examples of potential and existing wetland areas for the Stillaguamish Watershed with approximations of impacted or lost habitat.

Stream Name	WAU	Potential Wetland (area in ha)	Existing Wetland (area in ha)	Impacted or Lost (area in ha)
Church Creek	05-0412	1,030	360	680
Portage Creek	05-0401	860	390	480
Lower Pilchuck	05-0313	620	230	390
Total		2,520	970	1,550

Wetlands in the Stillaguamish Watershed can now be protected under the Snohomish County Critical Area Regulations (CAR). Protective buffers identified in the CAR range from 31 m (102 ft) for a Category 1 wetland, down to 8 m (26 ft) for a Category 4 wetland. The CAR permit is required when submitting a grading or building permit requiring the applicant to identify all critical areas affected by proposed activity. Identified critical areas are recorded at the assessor's office for protection in the future; they also are used as enforcement tools when permits have not been acquired.

The conversion of forested wetlands into drained agricultural land typically results in a loss of wetland function because many agricultural practices export large amounts of sediment and nutrients (Naiman 1990). An upstream loss of wetland habitat increases the amount of sediment reaching the mainstem and results in fine sediment intrusion into spawnable gravel. The Tulalip Tribes published a report (95-2 Assessment of the Water Quality of the upper Stillaguamish

River in Snohomish County, Washington 1991 – 1992) discussing the important relationship between suspended sediments and bacteria during storm events. Results indicated that restoration or enhancement of wetlands with functional potential could restore sediment storage and transform nutrients, reducing sediment and nutrient loading.

In general, wetlands provide rearing habitat and attenuate flows. The following is a list of additional wetland functions that are a direct benefit to maintaining quality salmonid habitat:

- 1) Temperature Maintenance
- 2) Sediment Retention
- 3) Nutrient Removal/Transformation
- 4) Nutrient Retention
- 5) Flood Flow Storage and Desynchronization
- 6) Base Flow Maintenance
- 7) Groundwater Recharge
- 8) Shoreline Stabilization
- 9) Food Chain Support

The greatest functional benefits to chinook may be temperature maintenance through base flow support, flood flow storage/desynchronization, and sediment retention. All of these functions provide values that help increase the chinook's chance of survival from the egg to returning adult stage.

Fish Passage Barriers

For many fish species, migration is essential for survival. For example, fish that travel from the sea to freshwater to spawn (anadromous) begin a maturation process that initiates when they reach their spawning habitat. Improperly selected and placed culverts can be barriers to such migration, thereby adversely affecting fish production and population sustainability. Unhindered fish passage at stream crossings is an important consideration in the engineering of extensive road networks throughout the Stillaguamish River Basin.

The majority of past research regarding fish passage at road drainage structures has been oriented toward adult anadromous fish. The traditional approach to assessing fish capabilities has been to divide swimming speeds of adult fish into various activity categories such as cruising, sustained, and burst speed. Although the majority of research on fish passage has historically been geared to adult anadromous fish passage, juvenile anadromous and resident species also exhibit a variety of upstream migrations (Baker and Votapka 1990). In a stream system managed for wild fish production, blocking juvenile fish movements into tributary streams can lower production by arbitrarily limiting the capability to rear fish and increasing juvenile mortality (Leider et al. 1986).

Historically, remnant mill ponds such as the Fortson Ponds on the North Fork and Gold Basin Ponds on the South Fork represented total fish barriers. Washington Department of Fish and Wildlife installed a fishway at the Fortson Ponds in 1983 and added a fish ladder to the culvert at Gold Basin Ponds in 1989. As a result, these ponds are now accessible to anadromous fish.

Currently, there are three projects in the Stillaguamish Watershed aimed at categorizing and prioritizing culvert blockages throughout the basin: 1) the Stillaguamish and Tulalip Tribes have completed an inventory of over 300+ culverts; 2) Snohomish County Surface Water Management has completed an inventory of culverts within the Stillaguamish Clean Water District; and 3) the Washington Departments of Fish, Wildlife, and Transportation keep an on-going inventory of “problem” culverts in the basin. The USFS also has a fish passage culvert condition inventory, however data for the Stillaguamish Watershed are limited. By combining the staff and funds of the above mentioned groups, approximately 15 culverts were repaired or are in the process of being repaired, resulting in 25 km (15.5 miles) of new habitat (Stillaguamish Salmonid Barrier Evaluation and Elimination Project, Stillaguamish and Tulalip Tribes 1998). An important component of culvert repair is effectiveness monitoring. Currently, spawning adults and juvenile fish populations are monitored above and below all culvert replacements.

Water quality degradation

Sufficient water quality is critical in protecting the various life stages of salmonids and other aquatic organisms. Human population growth in the Stillaguamish Watershed has led to increasing demands for more roads, sewage treatment plants, and commercial activities. Poor land use practices, urbanization pressures, and failure to enforce BMPs all have contributed to considerable nonpoint source pollution in the Stillaguamish Watershed.

The most common water quality issues in the Stillaguamish include runoff from commercial and non-commercial farms, failing septic systems, land clearing and construction, road surface runoff, and over allocation of water resources. A 1994 assessment by WDOE concluded that over 60% of the assessed river miles within the Stillaguamish were not suitable for salmon spawning. Natural, environmental variation and the interrelatedness of many water quality parameters make it difficult to pinpoint a single, specific factor that might be blamed for poor salmonid returns. However, collectively these practices degrade the water quality and habitat upon which salmon and other organisms depend.

The Stillaguamish River has experienced a deterioration of water quality, measurable by conventional parameters and microbiological standards. Reported violations of CWA water quality standards are increasing as evidenced by Washington State’s growing number of 303(d) listings in 1998 (Table 5). Problems have been found in both the mainstem and smaller tributaries, according to the Snohomish County Surface Water Management Division and others with monitoring programs in the basin (Figure 16).

Agencies working collaboratively within the watershed include the Stillaguamish Tribe, Tulalip Tribes, Snohomish County Surface Water Management Division, USFS, WDOE, WDNR, and the Washington Department of Health. The Tulalip Tribes began ambient monitoring in 1988, followed by the Stillaguamish Tribe in 1993, and Snohomish County in 1994. Over time, this monitoring effort in conjunction with other agencies has generated a database for areas throughout the watershed. These data provide a range of environmental variability upon which to assess changes in water quality and quantity. It is hoped that trends can be identified in the processes related to the degradation of aquatic resources.

Table 5. The 1998 list of impaired and threatened waterbodies identified by the Department of Ecology in the Stillaguamish Watershed.

Waterbody	Type of Pollution
Fish Creek	Fecal Coliform, Lead
Harvey Creek	Fecal Coliform
Higgins Creek	Temperature
Jim Creek	Fecal Coliform
Jorgenson Slough (Church Creek)	Fecal Coliform, Lead
Little Deer Creek	Temperature
Martha Lake Creek	Fecal Coliform
Old Stillaguamish River	Fecal Coliform
Pilchuck Creek	DO, Temperature, Lead
Port Susan	Fecal Coliform
Portage Creek	DO, Fecal Coliform, Turbidity
Stillaguamish River	Ammonia, Arsenic, Copper, DO, Fecal Coliform, Lead, Nickel, Temperature
North Fork Stillaguamish River	Fecal Coliform, Temperature, Lead, Copper
South Fork Stillaguamish River	DO, Fecal Coliform, pH, Temperature, Lead, Copper
Sunday Lake	Total Nitrogen, Total Phosphorus

The Stillaguamish Tribe's monitoring efforts (primarily in the upper watershed) include recording water temperature, DO, turbidity, alkalinity, hardness, total suspended solids, pH, and bacteria. Snohomish County conducts numerous investigations for nutrients, heavy metals, bacteria, and other toxicants mainly in lower portions of the river. In addition, the Tulalip Tribes have monitored the lower region of the Stillaguamish River. Recently, the Stillaguamish Tribe has expanded its monitoring to include most of the Stillaguamish River and some of the estuarine areas.

Water quality impacts to aquatic life can be measured by monitoring DO and water temperature. Salmon eggs show moderate impairment at DO levels of 8 mg/l, while adult salmon are moderately impaired at 5 mg/l. The optimal temperature range for salmon is 12-14°C (54-57°F), with lower temperatures preferred for spawning. Lethal temperature levels for adults are in the range of 20-25°C (68-77°F) (MacDonald et al. 1991).

Monthly monitoring data from the Stillaguamish Tribe and Surface Water Management from 1991 through 1998 indicate that DO in the mainstem usually falls within the preferred ranges for salmon. Dissolved oxygen in the tributaries to the Stillaguamish River usually meets or exceeds the standard of 8.0 mg/l. Monitoring in Pilchuck Creek, Church Creek, Fish Creek, and Tributary 30 (since 1991 by the Tulalip Tribes and Snohomish County) shows few violations of the DO standard. However, DO in lower Portage Creek ranges from 4-6 mg/l during much of the summer months.

Temperature measurements, collected by continuously recording temperature loggers, can record daily fluctuations and the extent of time that temperatures are stressful to salmon. A temperature

study conducted by the Stillaguamish Tribe, Tulalip Tribes, and Snohomish County in 1996, indicated that temperatures in both the mainstem and tributaries frequently increased into stressful ranges (Table 6).

Table 6. Summary of 1996 Stillaguamish temperature logger data, percentage of total time (June - September 1996) that temperatures were recorded in the following ranges.

Site	Preferred Range Less than 13°C (56°F) (%)	Stressful Range 13-20°C (56-68°F) (%)	Potentially Lethal Range Greater than 20°C (68°F) (%)
North Fork at C-post bridge	48	52	0
North Fork at Smokes farm	31	61	8
Mainstem at I-5	16	68	16
Portage Creek at Burn Rd.	78	22	0
Portage Creek at 212 th Bridge	34	66	0
Church Creek at Jensen Rd.	43	57	0
Pilchuck Creek at mouth	13	77	10

Conductivity is another parameter of surface water that is influenced by impacts due to urbanization. Conductivity is an indicator of dissolved ions in water, an increase in conductivity values can be an indicator of increased fertilizer runoff, land clearing, de-icing salts, and metals contained in road runoff. Snohomish County has recorded the lowest conductivity (around 50 umhos/cm) in the least developed watersheds and higher conductivities (from 100-200 umhos/cm) in areas with more commercial, residential, or agricultural development. From 1994 through 1999, Snohomish County found a statistically significant increase in conductivity in all of their monitoring sites throughout the Stillaguamish Watershed. This increase in conductivity may indicate a general increase of land use impacts to water quality in the Stillaguamish Watershed (Thornburg 2000).

The Stillaguamish Tribe placed Optic Stowaway Temperature Loggers in Hat Slough and portions of the estuarine waters of Port Susan from May through September 1998. Data indicate that salmon in Port Susan and the lower Stillaguamish estuarine areas are exposed to considerably high water temperatures during low flow and summer periods. Figures 17, 18, and 19 show water temperature readings on an hourly basis during the same time interval (July 23 – August 6, 1998) at three locations. Salmonid temperature thresholds (MacDonald et al. 1991) are placed within each graph for relative visual interpretation. The three temperature recording stations were not dewatered during the study. Water temperature data for the Stillaguamish Watershed indicate that temperatures in the stressful range were common during the low flow months from 1994 to 1998 (Table 7).

Table 7. Summary of water temperature observations for the Stillaguamish River, mainstem, and selected tributaries tabulated on a monthly basis (June – September, 1994 - 1998).

Site	Preferred Range Less than 13 ⁰ C (56°F) (#)	Stressful Range 13-20 ⁰ C (56-68°F) (#)	Potentially Lethal Range Greater than 20 ⁰ C (68°F) (#)	Total Number Of Observations
North Fork (NF) Stillaguamish:				
<i>Whitehorse Bridge (Swede Haven Rd)</i>	4	10	0	14
<i>Boulder River</i>	7	3	0	10
<i>Squire Creek</i>	9	4	0	13
<i>Montage Creek</i>	3	9	0	12
<i>NF. Stillaguamish at Whitman Bridge</i>	2	10	0	12
<i>Deer Creek at mouth</i>	2	6	3	11
<i>NF. at "C" Post</i>	1	1	0	2
South Fork (SF) Stillaguamish:				
<i>Canyon Creek at Masonic Park</i>	3	5	0	8
<i>SF. Stillaguamish at Jordan Rd</i>	5	6	3	14
<i>Jim Creek</i>	1	0	1	2
<i>SF. Stillaguamish (Twin Rivers Park)</i>	0	0	1	1
Mainstem at Arlington				
<i>Portage Creek at Burn Rd.</i>	5	10	0	15
<i>Pilchuck Creek at mouth</i>	0	5	2	7
<i>Mainstem at Silvana</i>	0	4	3	7

Figures 17 and 19 show water temperatures in the main Stillaguamish River channel, which is carved in the mud flats within the Hat Slough Estuary. Water temperatures above 21°C (69.8°F) are frequent in this estuary.

Site B (West Branch Hat Slough) is currently the second largest discharge outlet for the Stillaguamish River in North Port Susan. Minimum depth at extreme low water did not fall below 1.2 m (3.9 ft). Flood tides bring warm water from the muddy/sandy shallows into the estuary and Hat Slough areas, increasing the likelihood of disease, smolt stress, and migration blockage. Temperature ranges for 23 July 1998 were 19.9° C to 30.9° C (67.8-87.6°F) in an eight-hour period (Figure 17). Water temperatures at Kayak Point near the pier are as shown in Figure 18; this is the southernmost monitoring station and represents near open water surface temperatures. The thermograph at Kayak Point (Site D) is attached to a piling about 0.30 m (1 ft) from the bottom, approximately 46 m (151 ft) from shore; minimum depth is about 1.2 m (3.9 ft) at extreme low tide and maximum depth is about 4.3 m (14 ft).

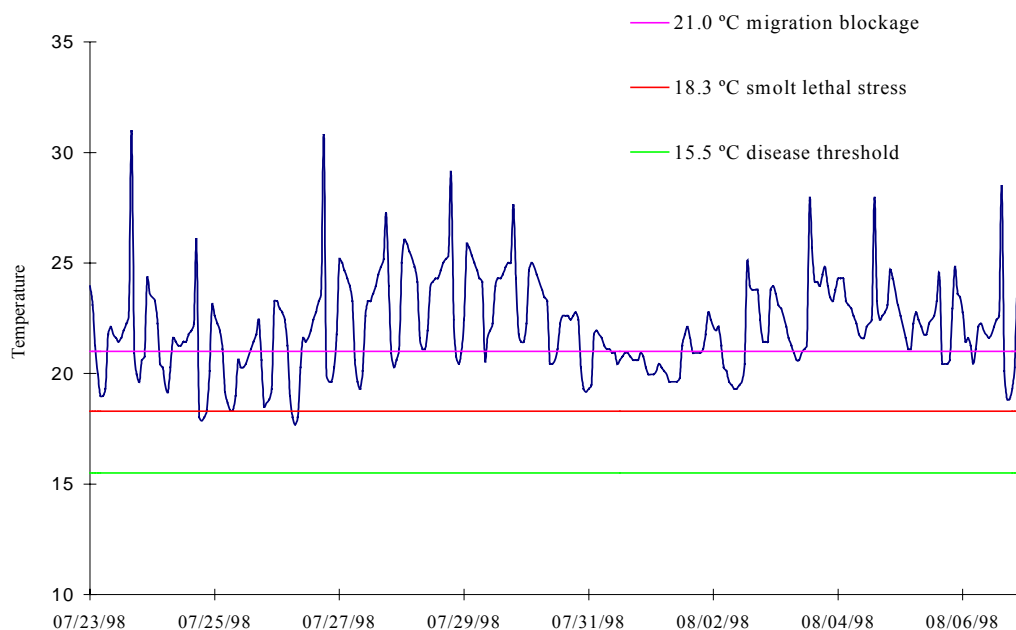


Figure 17. Water temperature readings (°C) on an hourly basis for West Branch Hat Slough (July 23 - August 6, 1998).

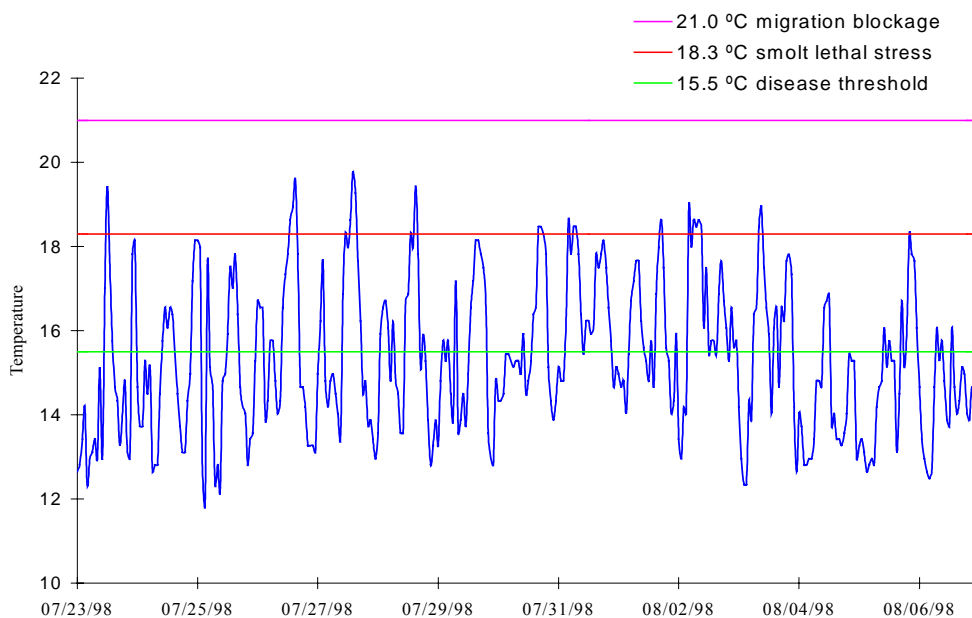


Figure 18. Open water surface temperatures (°C) on an hourly basis for Kayak Point (July 23 - August 6, 1998).

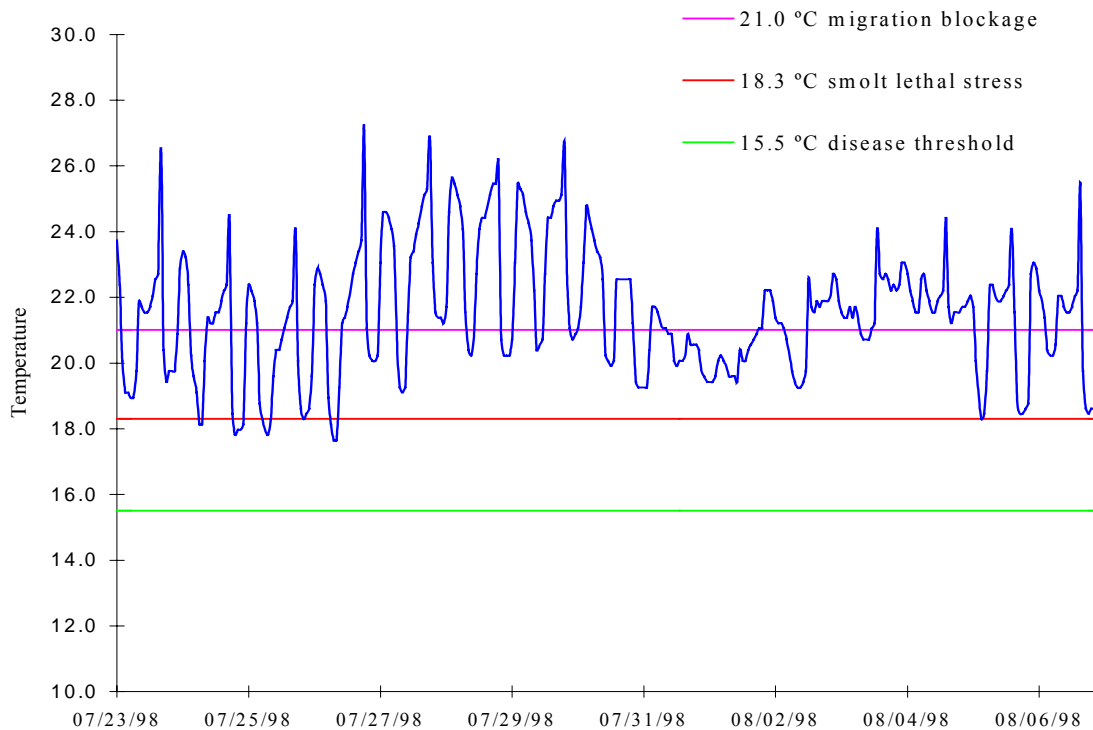


Figure 19. Water temperature readings (°C) on an hourly basis for Hat Slough Estuary (July 23 - August 6, 1998).

As mentioned before, sediment deposition adds stress during spawning, similar to the effects of increasing temperatures. Sources of the high sediment loading in the Stillaguamish Watershed appear to be the North and South Forks and upper tributaries. Sediment levels in the lower tributaries are typically less than those found in the upper regions. Since 1994, Snohomish County has measured mean concentrations of 50 mg/l of total suspended sediment in the mainstem Stillaguamish and mean concentrations of approximately 10 mg/l in tributaries of the lower mainstem.

In a 1995 study, the Tulalip Tribes concluded that on average the North Fork delivered over ten times the load of suspended sediment in comparison to the South Fork. The Tribes estimated that 1,422,400 kg (1,400 tons) per day of suspended sediment were produced in the North Fork and only 132,080kg (130 tons) per day in the South Fork. Tulalip identified the major sources of fine sediments on the North Fork as Deer Creek, Boulder River, Hazel Slide on the North Fork above Oso, and the agricultural reach between Oso and Arlington (discluding the canyon). The Stillaguamish Tribe also measured high sediment levels in Montague Creek. Sources of sediment in the South Fork originate from Redbridge, Gold Basin Slide, and Mallardy and Boardman Creeks. The Stillaguamish and Tulalip Tribes also found low levels of suspended sediment in Jim and Canyon Creeks.

Instream Structures

a) Cook Slough Weir

Downstream of Arlington, the Cook Slough Weir project is located approximately 0.8 km (0.5 miles) from the I-5 bridge. In 1939, the federal government authorized the Civilian Conservation Corps (CCC) to provide support to reduce bank erosion and channel changes on the mainstem between Arlington and Hat Slough, a distance of 24 km (15 miles). The project included revetments at 26 sites on the river and Cook Slough, and an 84 m (276 ft) control weir at the mouth of Cook Slough that limited flow through the slough and two cut off-channels (each about 274 m or 899 ft long) to minimize sharp bends. As a result, most of the flow was channeled via North Slough. Currently, the weir diverts the main flow of the river to Hat Slough.

With the elimination of the CCC, the Army Corps of Engineers and Snohomish County were responsible for maintaining the above project. The County was given the task of maintaining some of the revetments while the Corps maintains others as well as the weir. The Corps modified the weir in 1991 to allow fish passage during low flow periods; there is currently a fish passage structure associated with the weir. In drought years, some salmon (especially pinks) have had a difficult time migrating upstream through the weir. There also was an obvious impact on the historic hydrology of the river system, as a result of the revetments and weir. Flow patterns were altered, the river straightened, floodplain and sloughs were isolated, and the channel forming processes of the river diminished.

Under the Stillaguamish Ecosystem Study, there is a proposal to correct fish passage through the development of a new structure. This project would employ a baffle system designed by Ken Bates, State Department of Fish and Wildlife, and Corps staff. The new fish ladder would be located in the center of the existing weir, so that it could operate effectively under all flow conditions.

b) South Fork Fish Ladder

Historically on the upper South Fork of the Stillaguamish near Granite Falls, there was a large falls present in a narrow canyon resulting in a barrier to fish passage. It is believed that during historic times and at certain flow conditions, only summer and winter steelhead were able to migrate to the upper reaches beyond the falls. Pink, char, chum, chinook, and coho could make it up to the falls, but could not access the miles of habitat beyond this barrier.

In 1954, a fishway was built by what is now the Washington Department of Fish and Wildlife. The intent was to facilitate passage for many anadromous species that had previously been blocked. Currently, the fishway facilitates passage to the upper watershed, but does not always work in an optimal manner. There is a large sediment load associated with the South Fork and large amounts of gravel are deposited in the structure (these are periodically sluiced out). During summer low flows, especially in June and July, the fishway dewateres and occasionally strands fish. The Washington Department of Fisheries is cognizant of this problem and has developed a three-phase approach to improve the structure:

- *Phase One* - Upgrade fish safety (already completed).
- *Phase Two* - Manage gravels that enter the fishway, reduce maintenance needs and turbulence, and recontour the channel profile.
- *Phase Three* - Improve attraction water and construct an exit closure device.

While the actual fishway may be improved and passage facilitated, a larger question may be asked in light of ESA regulations. That is, providing access to areas that were not historically accessible to chinook and other salmon and at what cost to the native fishery upstream. Currently, under the Wild Salmonid Policy, it is unlikely that a structure such as this would be permitted. A counter argument could be that this improvement project provides a trade off for habitat loss downstream.

c) Hydropower

Historically, there were several small hydropower sites dealing with early mining and logging activities in the basin. At present, there are no major hydropower projects or dams on the Stillaguamish River, with the exception of the above-mentioned weir.

Disturbance Regime

Salmonid habitats are products of the interactions between geology and soils, topography, vegetation, climate, and hydrology within a watershed. Salmonids are adapted to a dynamic landscape. Native stocks of salmon, trout, and char that have evolved in stream systems with fluctuations in flow, turbidity, and temperature have often developed behaviors that enable survival, despite the occurrence of temporarily unfavorable conditions. However, natural or human-induced changes to environmental processes via land use practices can be large enough to prevent fish from completing their maturation or migration to spawning areas (Bjornn and Reiser 1991).

a) Mass Wasting

Mass wasting in the form of landslides, earthflows, slumps, and creeps is a major component of sediment delivery to streams. These periodic events deliver LWD and coarse, gravel-sized sediments to streams and rivers, providing cover and spawning substrate. Fish populations have evolved over time in stream channels that are in a relative balance between bedload transport and deposition. Periodically, high sediment influx affects fish habitat as the sediment settles in pools and low gradient areas; channels also may shift, altering fish habitat.

b) Habitat Connectivity and Fragmentation

A critical function of riparian habitat is to maintain the spatial and temporal connectivity within and between watersheds. The lateral, longitudinal, and drainage network connections include wetlands, upslope areas, headwater tributaries, and intact refugia. On Federally administered lands, these connections must provide chemically and physically unobstructed routes to areas critical for fulfilling life history requirements of aquatic and riparian-dependent species (USFS

and BLM 1994). Natural disturbances (e.g. fires) can lead to habitat fragmentation, but land uses such as timber harvest, urbanization, and agriculture result in the most intense and extensive fragmentation of salmonid habitat.

c) Timber Harvest

Removal of riparian (and upslope) vegetation has had a considerable effect on the landscape. See the Riparian Function and Riparian and Upland Clearing sections of this document.

d) Road/Railroad Construction

Road building associated with timber harvest and development has directly and indirectly affected the connectivity of aquatic habitats by:

- Impeding or blocking fish migration at road crossings.
- Increasing the drainage network and accelerating erosional processes.
- Changing the channel morphology associated with crossings.
- Accelerating sedimentation in streams associated with road-related failures, while also causing localized scour.
- Constricting natural sinuosity and floodplain function, particularly along the valley bottom.
- Promoting further development and associated human impacts.

In the Canyon Creek and South Fork Stillaguamish Basins (between Canyon Creek and Boardman Creek, inclusive), density of open roads is primarily between 0.8–1.2 km/km² (1.2–1.9 mi/mi²). Nearly half (48%) of this 30,100 ha (74,378 acres) area is in this category. Another 23% of this area has 1.2–1.9 km/km² (1.9–3.1 mi/mi²). The National Marine Fisheries Service (1996) suggests that a properly functioning watershed has <1.2 km/km² (1.9 mi/mi²), and also has no valley bottom roads.

B. HARVEST MANAGEMENT

1. Annual Management Forums

Chinook salmon from Puget Sound are harvested throughout their entire period of marine residency in a plethora of fisheries ranging geographically from Alaska to the ocean off the Washington coast and inside Puget Sound. In most cases, fishing mortality on Stillaguamish chinook salmon is incidental to fisheries targeting other stocks or species. Hook-and-line and net fisheries have not directly targeted Stillaguamish chinook since the early 1980s. In marine waters there have been no directed fisheries in Port Susan since 1984; marine hook-and-line recreational fisheries have been reduced over the years, and directed take stopped several years ago. Even with the cessation of directed fishing, incidental harvest rates can be considerable. The harvest management challenge has been to find ways to allow fishing on abundant stocks and species while minimizing the mortality of key wild management units, such as Stillaguamish chinook.

Harvest management of Stillaguamish chinook salmon is governed by the Pacific Salmon Treaty (PST), Pacific Fishery management Council (PFMC), and comanagement by the State of Washington and the Treaty Tribes under the Puget Sound Salmon Management Plan (PSSMP). Under the new annex of the PST adopted in 1999, harvest rate by all fisheries intercepting Stillaguamish chinook salmon is controlled by a complex formula, based on the abundance of Stillaguamish and other Puget Sound chinook stocks. Under current conditions of low abundance, the majority of the chinook salmon returning to the Stillaguamish River will be passed through to the spawning grounds. For example, in 1999 and 2000 adopted fishery management plans were projected to allow for, at most, an exploitation rate of 25% on this management unit.

Current management under the PST and PSSMP apparently meets the objectives of this plan, which are designed to provide a high probability that harvest-related mortality will not impede rebuilding. Once post-season data are available, we will evaluate the results of implementing these management plans to assess whether the objective is being met, and to determine if modifications to the management objective are necessary.

2. Tribal Fisheries Impacting Stillaguamish Chinook Salmon

Stillaguamish chinook are vulnerable to fishing mortality throughout the year in the usual and accustomed fishing areas of many of the treaty tribes. However, in response to conservation concerns, tribal fisheries are closed in most areas and during times when Stillaguamish chinook are present. Beginning in 1982, there were no tribal fisheries specifically directed at Stillaguamish chinook. The few tribal fisheries directed at chinook, captured Stillaguamish fish at low rates. A number of tribal fisheries have an incidental mortality of chinook, including Stillaguamish fish, while in pursuit of other salmon species.

Tribal chinook-directed fisheries include: the Stillaguamish Tribe's subsistence fishery (not opened in 1999, limited to 25 fish or less in prior years); the Tulalip Tribe's fishery in Area 8D, directed at Tulalip Hatchery chinook; the treaty troll fishery in the Strait of Juan de Fuca; and the treaty ocean troll fishery.

Incidental harvest of Stillaguamish chinook occurs in in-river tribal fisheries directed at:

- Pink (odd-years only) and coho.
- Marine terminal area fisheries, directed at pink (odd-years only) and coho.
- Marine preterminal area fisheries (primarily in the San Juan Islands and Strait of Juan de Fuca), directed at pink (odd-years only) and sockeye.

Some incidental harvest of Stillaguamish chinook also occurs in the mixed-stock fishery in Area 10 directed at South Sound coho.

For 1999 preseason planning, the sum total of all the above directed and incidental impacts in tribal fisheries is projected to be 7.3% of the adult-equivalent harvest plus escapement of Stillaguamish chinook, or an estimated total impact of 127 fish.

3. Harvest Profile

Given the reduced fisheries planned in all areas for 1999, spawning escapement is expected to comprise 76% of the combined adult-equivalent harvest, plus escapement for the Stillaguamish chinook management unit³. The fishery-related impacts are spread among several fishing sectors (Figure 20). As described above, these are mostly incidental impacts in fisheries that have been mitigated to one degree or another to minimize mortality of chinook stocks of concern.

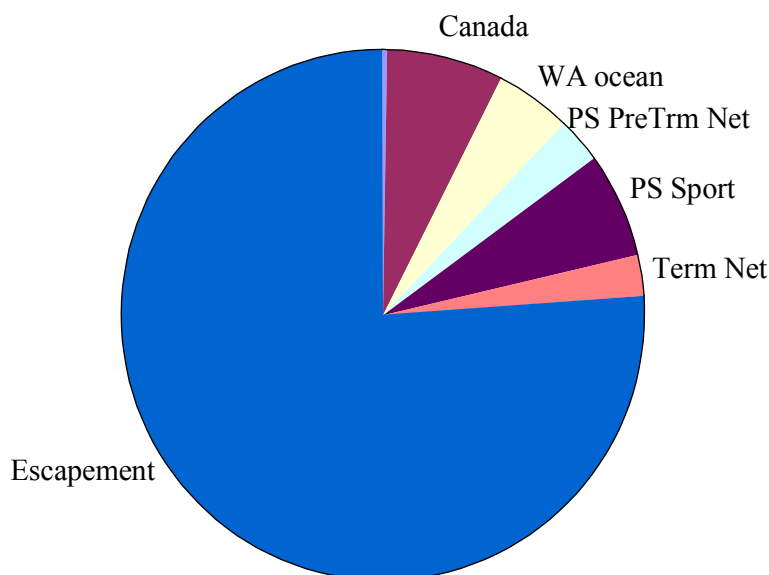


Figure 20. Stillaguamish harvest impacts by sector (1999).

The situation for 1999 is in marked contrast to earlier years when fisheries, although typically limited to incidental impacts only, were not as greatly restricted for chinook impacts as they were in 1999 (Figure 20). Figure 21 shows the distribution of adult equivalent (AEQ) fishing mortality for the Stillaguamish chinook management unit averaged over the 1980 through 1986 brood years⁴. In this case, the spawning escapement comprised 45% of the total. Harvest-related impacts were largely in Canadian and Puget Sound sport fisheries; reductions in these fisheries has most likely led to the larger escapement fraction predicted for 1999.

³ The information presented here is taken from Fishery Resource Analysis & Monitoring (FRAM) model run 0799.

⁴ The information on distribution of fishing mortality is taken from Puget Sound Salmon Stock Review Group (PSSSRG 1992) Assessment of the status of five stocks of Puget Sound chinook and coho. Overall fishing mortality is taken from PSSSRG 1997 update. Both reports are available from the Pacific Fishery Management Council in Portland, OR.

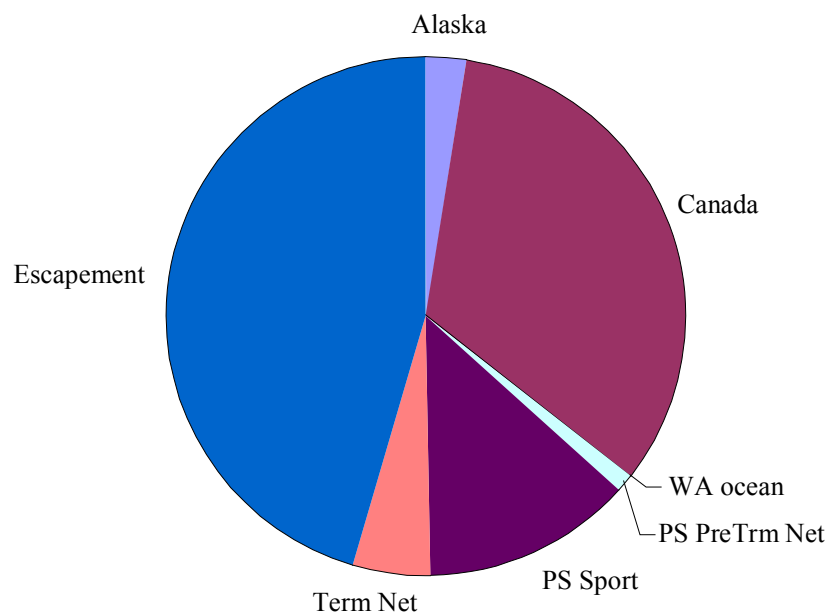


Figure 21. Stillaguamish chinook harvest averaged over the 1980-1986 brood years.

C. HATCHERY EFFECTS ON CHINOOK SALMON POPULATIONS

Hatchery production has been viewed by the general public and resource managers as the solution to habitat degradation. Loss of natural production is simply replaced with hatchery-produced fish. Comparatively less emphasis and money has been placed on protecting and restoring habitat to support naturally producing populations (White et al. 1995). In addition, the potential demographic impacts to wild populations from hatchery supplementation programs can be considerable. The rearing and release of salmonids from hatcheries may have several potential impacts on naturally produced chinook. Those potential impacts may be divided into two areas, ecological impacts and genetic impacts.

1. Ecological Impacts

Ecological impacts result when cultured fish and naturally rearing fish interact in the natural stream environment. Such interactions may include competition for food and space, predation, and disease transfer. Ecological impacts may also result from interactions between cultured fish and other species within the watershed. These interactions may provide sources of nutrients or a food supply for other animals.

Nickelson et al. (1986) documented cultured salmon displacing wild salmon from their habitats. This displacement effect results when large numbers of cultured fish are released into a stream environment. The longer the cultured fish are in freshwater, the more extensive the displacement impact. Fish that are close to smoltification at release are less likely to interact with and displace wild fish; however, they may compete with naturally rearing salmonids for food resources. Hawkins (1998) observed hatchery reared coho, steelhead, spring chinook, and cutthroat smolts

feeding on natural fall chinook fry in direct competition with natural coho, steelhead, spring chinook, and cutthroat smolts.

Research by Beamish et al. (1993) on the relationship between hatchery/wild production and large-scale shifts in marine productivity has shown evidence for a limitation on marine carrying capacity for coho and chinook. The release of more than 80 million hatchery coho and chinook smolts may directly compete and possibly limit wild coho and chinook marine survival during periods of low ocean productivity.

Ecological impacts may also result from increased predation by birds, mammals, and other fish on both hatchery and natural rearing chinook salmon, due to the increased concentration and numbers of fish available (Li et al. 1987; Steward and Bjornn 1990; Allendorf et al. 1997). Wood (1987) documented Common Mergansers, targeting hatchery-reared outmigrants in the near shore estuary environment.

The transfer of diseases from hatchery fish to wild fish has been documented, with expansion of the whirling disease throughout much of the Rocky Mountain states and into the Pacific Northwest. This disease expansion is thought to be associated with the planting of hatchery-reared rainbow trout.

Streams in western Washington are considered to be nutrient deficient for compounds such as nitrogen (Larson 1979). When anadromous fish return from the ocean, they bring with them considerable amounts of nutrients, which are eventually dispersed back into the watershed. Michael (1998) estimated that currently, returning hatchery and wild salmon to the Skagit system contribute more than one million kg of biomass back to the freshwater environment. Research by Bilby and Bisson (1987) found that an estimated 42% of the nitrogen in aquatic insects came from nutrients released by decomposing salmon. Juvenile coho and steelhead from the same watershed were found to have 38 to 45% of their carbon content derived from ocean-origin carbon.

Michael (1998) estimated that only 46 to 65% of the total nutrient requirements for the Skagit ecosystem were being met after current escapement (1.3 million kg or 98.7 tons) and hatchery production goals. In order to fully meet the nutrient needs of Skagit ecosystem, an additional 1.1 million kg (1,083 tons) of salmon carcass biomass would be required each year. Gresh et al. (2000) estimated that Pacific Northwest rivers currently receive only 6 to 7% of the historic levels of marine-derived nutrients from salmon than they did prior to European settlement.

2. Genetic Impacts

The culturing of salmonids in an artificial environment such as a hatchery may impact a number of genetic factors for the wild/natural spawning population. Genetic impacts may include the altering of the genetic population structure, declines in long term fitness, and other impacts that are not reflected in population abundance (Busack and Currens 1995). Diversity and fitness loss are two main areas of genetic hazard resulting from the rearing and release of salmonids into the natural environment.

Diversity is defined as the biological/behavioral differences that exist between individuals, groups of individuals, or between species (Currrens 1998). Diversity may be lost among different populations of the same species. An example of this would be a loss of diversity between the summer chinook populations in two separate watersheds, due to extensive straying between watersheds. Conversely, while outbreeding is undesirable from a production point of view, it can be argued that it could increase diversity (Kraemer pers. comm. 2000). Loss of diversity also may occur within a single population. An example of this would be a population of chinook where only fish ready to spawn before September 1st were used in a hatchery program.

Hard et al. (1992) defined fitness as an individual's contribution to the breeding population in the next generation and the fitness of a group/population or as the group's ability to maintain itself in its environment. Their analysis examines two breeding mechanisms that create a loss of fitness in a population. *Outbreeding* depression is the reduction in fitness that results from mating between unrelated or distantly related individuals. Outbreeding depression may result from loss of local adaptation or from the breakup of gene combinations favored by natural selection. *Inbreeding* depression is the reduction in fitness resulting from mating between close relatives that occurs by chance in small populations or by assortative mating in large populations.

Domestication is the third fitness-limiting mechanism. It is defined as natural selection that operates on a population during artificial production to produce genetic changes favoring fish adapted to surviving in a hatchery rather than in the natural environment (Doyle 1983). Should domestication occur in a hatchery population that interbreeds with a wild population, the consequence can be the loss of fitness in the wild population. The mechanisms for inducing domestication are intentional or artificial selection; inadvertent or non-random selection; the relaxation of selective constraints, and the unintentional or natural selection that occurs in the hatchery environment (Campton 1995). Examples of these mechanisms include selecting only the largest fish for spawning, taking brood stock where there might be two separate stocks intermixed, and using brood stock that are from a stock outside the watershed.

Loss of diversity within populations may result in short term loss of fitness due to inbreeding depression and less buffering against environmental variability, loss of local adaptations, lower natural productivity, loss of evolutionary potential, and lower sustainability. The major mechanism for loss is the non-representative reproduction of a subset of a population (NMFS 2000). An example of this would be taking only 10% of the population for brood stock and having the offspring from those matings represent 90% of the returning adults.

When outbreeding depression occurs, a reduction in population fitness may occur; mechanisms that cause the reduction are the mixing of incompatible genetic traits and the loss of local adaptation (NMFS 2000). The key mechanism for this is the straying of fish from outside the watershed into the naturally spawning population at a level that compromises the productivity of that population.

When large numbers of artificially produced fish stray into a natural population, an overestimate of natural abundance may result, thus masking the health and status of the population. The

mechanism for this impact is the release of unmarked hatchery fish in conjunction with incomplete surveying of the wild/hatchery ratio within the population. Natural origin recruits (NORs) from hatchery fish can also contribute to this impact (Ford and Waples 1998). In addition, the removal of brood stock from a small or depleted population may result in an increased risk for extinction due to isolation from other populations and decreased population size (Hanski 1991; Sjogren and Per-Ivan 1993).

Increased hatchery production, theoretically makes more fish available for harvest, which has increased the harvest pressure on wild salmon intermingled in pre-terminal mixed stock fisheries (Lichatowich and McIntyre 1987). Increased numbers of harvestable hatchery fish have driven the expansion of commercial and sport fisheries, which in turn pressure managers to keep hatchery production and harvest levels elevated (Lichatowich and McIntyre 1987).

3. Analysis of the Current Chinook Natural Stock Restoration Program

Federal, State, and Tribal technical specialists are developing a draft Comprehensive Chinook Management Plan (CCMP) as an operational plan to implement the state/tribal Wild Salmonid Policy. The draft CCMP (1998) plan has components to address all of the major areas of chinook recovery within the state. The artificial production portion of the plan provides basic principles and guidelines for the use of artificial propagation within Washington State. The artificial production section includes a framework for assessing the potential benefits and risks to natural populations through a benefit/risk analysis of artificial production programs.

Benefit Assessment

The CCMP Benefit Assessment for integrated recovery hatchery programs, including the Stillaguamish program, focuses on two objectives: 1) increasing the total (hatchery plus wild) abundance of a population, and 2) increasing the number of NORs. Both can be considered to be biological goals that are aimed at primarily improving the status of a stock by lowering the extinction risk (CCMP Workgroup 1998).

The first objective of CCMP is increasing total (hatchery plus wild) abundance. The Stillaguamish Chinook Natural Stock Restoration Program has contributed between 30 to 40% of the spawning adults returning to the North Fork Stillaguamish between 1989 and 1997. With annual releases of between 100,000 and 200,000 smolts, returns of 30 to 40% would indicate that the spawner replacement ratio is significantly higher for the artificially propagated fish than for the naturally spawning fish. The probability of this benefit occurring has therefore been ranked as high.

Consequently, the second goal is increasing the number of NORs. In order to increase the number of NORs, the spawner replacement ratio must be higher for the artificially propagated native stock fish. The number of program fish (fish produced by the Stillaguamish Hatchery), NORs, and wild fish should not exceed habitat capacity or result in reduced productivity (Currrens and Ford 1999). The probability of this benefit occurring has been ranked as high.

Risk Assessment

The risk assessment process uses a series of worksheets to evaluate artificial production hazards to natural populations. The first hazard for assessment is the negative effects associated with the reduction in the effective number of breeders. Negative effects include inbreeding depression, loss of genetic variation, and the accumulation of deleterious mutations. To minimize these effects, program fish need to be marked to accurately estimate the proportion of program fish to wild fish spawning naturally in the target population. There must be regular monitoring of the naturally spawning population and the effective breeding size for the production program needs to be greater than 250 fish. The current chinook natural stock restoration program marks 100% of all chinook smolts released. In addition, extensive spawner surveys are done each year to assess hatchery/wild spawner ratios and the 5 x 5 spawning matrix ensures an effective breeding population of greater than 250 fish. The probability that these guidelines will be met has been ranked as high.

The second hazard assessment concerns domestication. The negative effects of domestication include the loss of fitness within the wild population. Criteria that are included in the assessment matrix are:

- The status of domestication between project fish and the wild population.
- Biological traits of the wild population.
- Similarities between biological traits of project fish and wild fish.
- Representative population subsampling during brood stocking.
- Similarities in mating and rearing between project fish and the wild population.

There are a number of assumptions about the current chinook restoration program that have not been verified concerning the biological similarity between brood stock fish and the natural population. The current mating and rearing protocols for project fish are not similar to wild fish. Therefore, the probability of meeting guidelines has been ranked as moderate.

The third hazard assessment is the loss of within-population diversity. Hazards for this assessment include loss of fitness, decreased environmental buffering, loss of evolutionary potential, and lower sustainability. The criteria for this assessment include correct identification for all chinook populations; the selected brood stock source should be similar to the target population; and the correct brood stock must be collected. The chinook populations within the Stillaguamish have been identified using electrophoresis. Brood stock are collected from the wild population to be supplemented and some culling of stray fish from outside the population is feasible. The probability of meeting the guidelines has been ranked as moderate to high.

The fourth hazard assessment is the masking of the population status. Concerns for this assessment are that returning, unmarked project fish from the artificial production program will mask the actual number of wild fish and the consequent changes in population trends. In order to avoid masking hazards, a high percentage of the project fish must be marked and extensive spawner surveys are necessary to monitor the hatchery/wild ratio. Given that the current artificial production program marks more than 90% of the fish for release and extensive spawner surveys

are completed each year, the probability of meeting the masking guidelines has been ranked as high.

The final portion of the benefit/risk assessment is a matrix for determining the net biological benefit of an artificial production project on the target population. The components of this matrix include the criteria for assessing the risk of extinction, reduction in short-term extinction risk, and the improved natural population status. Based on 30 years of escapement estimates, limiting factors analyses, and habitat assessments, there is a high risk that the natural population will be smaller than 2,500 fish per generation and that a chronic decline has occurred and continues to occur. The artificial production program for Stillaguamish chinook has a high probability of increasing total abundance and a low probability of reducing the effective breeding population below 250. Populations within the Stillaguamish Watershed are correctly identified, program fish are marked and extensive spawner surveys are completed. In addition, domestication will be moderate and the ecological impacts to other populations and species should be acceptable. Therefore, the project has a moderate to high probability of being a net biological benefit to the target population.

There are many other factors that go into evaluating the overall risks and benefits of a given artificial production program. The target population size may be so low and unstable that it is acceptable to run a high-risk, artificial production program because the risk of total population loss is greater. Habitat conditions may be so degraded that there is a greater risk of extinction by not implementing an artificial production program. In evaluating a hatchery program, benefit/risk analysis must also be applied to habitat recovery plans and harvest management plans in an ecosystem-wide approach.

D. POACHING IMPACTS

Absolute poaching impacts to Stillaguamish summer chinook are unknown. Natural resources staff from the Stillaguamish Tribe annually and consistently recover heavy-duty hooks and line from the Stillaguamish River during the early fall brood stocking period. These recoveries occur in a section of river that is closed to all fishing except fly-fishing for summer run steelhead. In addition, natural resource staff have also recovered un-detonated explosives and illegal nets from the lower mainstem Stillaguamish River.

Kraemer (1999) of the WDFW released marked adult chinook above a rack on the Wallace River in the Snohomish Watershed and estimated that he lost 50% of the fish to poaching; there was little evidence of animal predation on these tagged fish.

Both WDFW and Tribes have underfunded and understaffed fisheries enforcement departments. Lack of personnel and the large geographic area requiring coverage, restricts the effectiveness of deterring poaching incidents. Based on the amount of illegal fishing gear recovered in the Stillaguamish, poaching continues to be a problem in the watershed. The degree of loss due to poaching or other unidentified mortality factors is unknown.

E. ESTUARINE/OCEAN PRODUCTIVITY CHANGES

A considerable amount of research has documented cyclical changes in ocean conditions, which have significant impacts on the marine survival of salmon. The Pacific Decadal Oscillation is a 20 to 30 year cyclical climate change that affects ocean currents and primary productivity (Mantua et al. 1997). Decadal shifts in the Aleutian low-pressure cell affect changes in the strength and direction of the California and Alaskan currents. These changes in direction and flow affect ocean temperatures, which in turn can affect productivity and salmon survival (Pearcy 1992). El Nino/La Nina events are changes in sea surface temperatures that are driven by air-sea interactions in the tropical Pacific. Major El Nino events have occurred in 1982-83, 1986-87, 1992-93, and 1997-98 (Pearcy 1997). During major El Nino events, sea surface temperatures off the western United States increase considerably, reducing upwelling, productivity, and allowing for the northward migration of pelagic fish species not typically found off the northern coastal areas (Pearcy 1992).

Although marine survival levels for chinook fluctuate widely, decadal shifts in marine conditions may have led to reductions in overall marine survival for Puget Sound chinook. Analysis done for the PSC (Jim Scott pers. comm. 1999) showed a significant decline in marine survival of Puget Sound hatchery chinook salmon, during the 1975 to 1994 period. This decline may have been as great as fourfold. Major declines in marine survival for coastal Oregon coho have also been reported for the same time period (Pearcy 1992).

Research by Ebbesmeyer et al. (1989) evaluated decadal-scale changes in deep water input to the Puget Sound, which led to significant changes in plankton production (Pinnix 1998). Record red tide blooms and increasing *Heterosigma* toxic blooms did not occur until the late 1980s (NOAA/NFSC 1999). These decadal changes in primary productivity may be connected to the decline of forage and bottom-dwelling fish species in Puget Sound over the last 20 years. In addition to productivity changes, the effects of estuarine and oceanic shifts in temperature, salinity and current direction must be taken into consideration when developing and evaluating habitat, harvest, and hatchery recovery plans.

F. PREDATION ON CHINOOK

1. Salmonids

Outmigrant predator/prey studies by Hawkins (1998) on the Lewis River found that both hatchery and wild salmonid smolts significantly impact rearing juvenile fall chinook through predation. Wild steelhead, cutthroat, and coho smolts had higher predation rates than their hatchery counterparts. However, there was a greater impact on juvenile fall chinook by hatchery smolts as a result of their larger numbers at release. Hawkins (1998) estimated that in 1997, more than 1.2 million wild juvenile fall chinook were consumed by 4.3 million yearling hatchery smolt (coho, chinook, and steelhead) planted in the Lewis river. In comparison, an estimated 7.5

million natural chinook fingerlings were consumed by 532,000 yearling hatchery chinook on the Feather River (Sholes and Hallock 1979).

However, a local outmigrant study of Skagit River hatchery steelhead (Kraemer pers. comm. 1994) found no evidence of chinook fry in the stomachs of the 150 fish examined. Outmigrant steelhead move quickly out of the near shore area, and consequently their impact on near shore food resources is minimal.

Outmigrant chinook from the Stillaguamish Tribal chinook program may prey on chum fry in the near shore environment during outmigration. Most pink salmon outmigrants leave the system prior to the chinook outmigration. Currently, Stillaguamish chum and pink runs are considered healthy stocks.

2. Mammals

There are three major mammalian predators of salmon that occur in Puget Sound and coastal Washington: 1) California sea lions, 2) harbor seals, and 3) killer whales. Other non-marine mammalian predators include river otter, domestic dog, and bear.

California sea lion counts over the last 15 years in Everett, Washington have shown an increase from 108 animals in 1979 to 1,113 animals in 1995 (NMFS 1996b). The 1995 analysis of mark and recapture data indicates that the 1,113 animals counted in 1995 may represent only 50-55 % of the total Puget Sound population (NMFS-AFSC unpublished data). Scat samples containing salmonid remains have been reported in the range of 6-54% of the samples checked depending on sample time and location (Roffe and Mate 1984; Gearin et al. 1986).

Observations of California sea lions at the Ballard Locks have documented consumption of up to 65% of the returning winter run steelhead, along with returning adult coho, sockeye, and downstream migrating smolts (NMFS 1995). Sea lions have been documented swimming as far upstream as Willamette Falls (43 km or 27 miles) and have been observed 13 to 16 km (8-10 miles) up the Snohomish River pursuing returning adult salmon (NMFS 1997). Recorded sea lion predation rates on salmon have ranged from 136 adult coho in 62 hours (NMFS 1996b) to 84 adult steelhead in 56 hours (Gearin et al. 1986). The National Marine Mammal Laboratory (NMML) estimated that California sea lions consumed an average of 830 metric tons of fish from Puget Sound during 1996 (NMML 1996).

Harbor seals are another major marine mammal predator of salmonids. The Washington State population of harbor seals has increased by approximately 7.7% annually between 1978 and 1993 (Huber 1995). The estimated population size for Puget Sound was 1,787 animals in 1993 (Huber 1995). As many as 300 harbor seals have been observed hauled out on log booms at the mouth of the Snohomish (NMFS 1997), and seasonal counts at the mouth of the Stillaguamish River have yielded over 100 animals (Klopfer pers. comm. 1999).

The occurrence of salmonid remains in scat samples has ranged from 20%, found out of 186 samples collected (NMFS-AFC 1996), up to 60% in samples taken from Columbia River harbor seals (NMFS 1997). Numerous researchers have observed harbor seals eating both adult and juvenile salmonids (NMFS 1997.) Harbor seals also have been observed foraging on outmigrant chum fry and coho smolts at night using bridge lights to facilitate their capture. Olesuik (1996) from the Canada Department of Fish and Wildlife estimated that harbor seals consumed 3.1 million chum fry and 138,000 coho smolts migrating in the lower Puntledge River in BC. These predation levels represented 7-31% of the chum production and 15% of the coho production for the Puntledge River during 1995. In 1993, the NMML estimated that within Puget Sound 1,787 harbor seals consumed 1,649 metric tons of fish. Within the Straits and San Juan Islands, NMFS (1997) estimated that 9,953 harbor seals consumed over 9,000 metric tons of fish.

In conjunction with considerable increases in the numbers of sea lions and harbor seals, there have been abrupt declines in some of the key forage fish stocks that provide food for these animals. For example, Pacific whiting (hake) populations in Port Susan are at 1/40 the population size measured in the mid 1970s (WDFW 1999). Both herring and Pacific whiting have been petitioned to NMFS for listing as threatened, along with 13 other pelagic fish species within Puget Sound (Palsson 1999).

Killer Whales are the third major marine mammal predator of salmon both within Puget Sound and off the coast of the Pacific Northwest. Current counts have documented the Puget Sound population at approximately 89 individuals and north coastal population at approximately 209 individuals. The Puget Sound killer whale population has been documented eating primarily salmon during residence time and researchers have estimated that an adult killer whale can consume up to 91 kg (200 lbs) of fish per day.

3. Birds

Bird predation is a component of overall loss of salmon at all life stages. Like other predators, bird species vary in relative population numbers over time. The overall impact of bird predation on salmon survival is unknown. Ring-billed Gulls, Common Mergansers, Great Blue Herons, Double-crested Cormorants, Western Gulls, Caspian Terns, and Belted Kingfishers forage throughout the Stillaguamish Watershed and estuarine areas, potentially impacting the total number of outmigrant chinook. A cormorant rookery exists at the mouth of the Snohomish River and its numbers have expanded from less than 100 pairs to over 200 pairs in less than 10 years (Kraemer pers. comm. 1999). Currently, there are several major Blue Heron rookeries on the Tulalip Indian Reservation, which include over 150 birds (Bengston pers. comm. 1999). In addition, Common Mergansers are routinely seen during field activities by Stillaguamish Tribal natural resources staff (Killebrew pers. comm. 1999). Wood (1987) completed studies of merganser foraging impacts on several streams on Vancouver Island, BC. Daily fish consumption by merganser ducklings ranged from 80% of body weight for ten-day-old birds to 40% for 40-day-old ducklings. Predation by mergansers accounted for up to 10% of the total mortality of outmigrating salmonids in Vancouver Island streams. Additional studies by Wood (1987) on the Big Qualicum River, documented mergansers feeding almost exclusively on

outmigrant salmonids and seasonal consumption was estimated at 80,000 to 131,000 coho fry. Wood and Hand (1985) estimated that an adult merganser would consume about 400 g/day (0.9 lbs/day) of fresh fish.

G. NON-NATIVE SPECIES

Introduction of non-native aquatic nuisance species into the marine and freshwaters of Washington threatens the ecological integrity of the State's water resources, as well as economic, social, and public health conditions. Because they have few natural controls in their new habitat, they spread rapidly, destroying native plant and animal habitat. Non-native species considered to be priority species and worthy of immediate or continued management action include:

Animals

- Zebra mussel (*Dreissena polymorpha*)
- Chinese mitten crab (*Eriocheir sinensis*)
- European green crab (*Carcinus maenas*)

Plants

- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Hydrilla (*Hydrilla verticillata*)
- Brazilian elodea (*Egeria densa*)
- Parrotfeather (*Myriophyllum aquaticum*)
- Purple loosestrife (*Lythrum salicaria*)
- Saltcedar (*Tamarix ramosissima*)
- Smooth cordgrass (*Spartina alterniflora*)
- Common cordgrass (*Spartina anglica*)
- Japanese knotweed (*Polygonum cuspidatum*)
- Giant knotweed (*Polygonum sachalinense*)
- Reed canary grass (*Phalaris arundinacea*)

Of the above species, only cordgrass (*Spartina sp.*) has apparent direct impacts to chinook life histories. The transition of intertidal acreage in the Pacific Northwest from the present species assemblage to *Spartina*-dominated salt marsh is accompanied by two groups of displacement features. The first is the physical exclusion of species typically found in the intertidal region. These species include eelgrasses, Dungeness crab, clams, juvenile fish (of many genera), shorebirds, and waterfowl. The second displacement feature is the trapping of sediments, *Spartina* can capture up to 15 cm (6 in) of new material annually. The eventual consequence of *Spartina* growing in estuarine environments is the removal of intertidal acreage to salt marsh at and above mean ordinary high water. There are extensive populations of *Spartina* in Port Susan and South Skagit Bay, which may pose a considerable threat to juvenile chinook populations.

Aquatic and submergent plants dramatically affect lakes and wetlands by displacing native flora and fauna and creating unnatural nutrient conditions. However, impacts on adult or juvenile chinook salmon are not well understood. Indirect impacts to chinook salmon are increasing as Japanese knotweed and reed canary grass out-compete native flora and reduce the survival and recruitment of large riparian vegetation necessary for creation of fish habitat, shade, and cover. While the non-native animals listed above may displace native species and negatively impact chinook, they may still provide a food base for chinook juveniles in the estuary environment.

H. CLIMATIC SHIFTS

Climatologists have documented a number of cyclical changes that occur in surface temperatures and precipitation levels, which affect streamflow and water temperature in the Pacific Northwest. These climatic shifts were documented by numerous studies of tree ring growth, weather observations, and streamflow data. Mantua et al. (1997) categorized them as 20-to 30-year independent shifts in precipitation and air temperature. The period from 1976 to 1994 represented an especially dry and warm period for the Pacific Northwest (Mantua et al. 1997).

Climatic shifts cause considerable changes in the weather, which in turn affect stream conditions for anadromous salmonids. During dryer, warmer periods less snow pack develops, and what is available melts more quickly, increasing flooding potential. In summer, when air temperatures are higher, decreased snow pack and precipitation lead to lower streamflows with higher water temperatures. Flooding during the winter and spring impacts egg and fry survival, while lower flows in summer impact the amount of water available for adult migration and spawning.

Although the Pacific Northwest was in a dry, warm period from 1976 to 1994, Collins (1997) documented 10 of the largest flood events on record for the Stillaguamish during this time. The flow regime differences for the Stillaguamish have been attributed to the considerable harvest of timber from the watershed during that period.

Changes in climate and consequent shifts in weather and streamflow can have a dramatic effect on chinook survival during the freshwater phase of their life cycle. Recent analysis of flow/smolt relationships on the Skagit River (Seiler et al. 1998) revealed a 20-fold decrease in egg to smolt survival (estimated at only 1%) during the 1990 flood. In years where no flooding occurred, egg to smolt survival was approximately 20%.

V. DESIRED FUTURE CONDITIONS

A. GOAL

To protect, restore, and enhance the abundance, geographic distribution, and diversity of all stocks of wild chinook salmon produced in the Stillaguamish River Basin, to a level that will sustain fisheries, non-consumptive fish benefits, and other related cultural and ecological values.

B. OBJECTIVES

1. Future Conditions of the Salmon Resource

The overall objective of listing the Puget Sound chinook as threatened is to comply with ESA and restore the ESU to a self-supporting population that does not require legal intervention to maintain its existence (NMFS 2000). Within the Stillaguamish Watershed, the primary objective is to restore chinook to a level where natural stock production is healthy enough to support sustainable recreational and commercial fisheries; specifically, the objective for recovery is the re-establishment of healthy, viable populations within the Stillaguamish Watershed. Viable populations refer to those populations that have a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year timeframe (NMFS 2000). Populations or stocks are defined for the purposes of this report as a group of fish spawning in a particular lake or stream segment during a particular season, where the fish (to a substantial degree) do not interbreed with any other group spawning in a different place or the same place during a different season (Ricker 1972).

A viable salmon population has four components that are used to determine relative health (NMFS 2000). Geographic distribution is assumed to be a key factor in maintaining variation and genetic diversity and underlies each of the following components:

- Abundance;
- Productivity;
- Population Structure; and
- Diversity.

Abundance, the first component, is generally measured in terms of population size. Genetic risks of low abundance include inbreeding depression, mutation accumulation, and the overall loss of genetic diversity (Currens and Ford 1999). The current range for abundance for a healthy population is 1,250 to 2,500 returning chinook per year based on the dominant age of four year old fish (WDF 1993). In the analysis of 34 healthy chinook stocks/populations, WDF (1993) found the five-year geometric mean to be 1,825 fish per year. When there are higher levels of environmental variability, a higher population size is required to maintain the population at a healthy level.

The second component is productivity, which is the population's potential for increasing or maintaining its abundance over time. A continuously negative productivity value may lead a population toward extinction (NMFS 2000). Productivity is most commonly measured as a function of trends in abundance. When there are naturally spawning hatchery fish, abundance trends need to be adjusted to reflect those "added" fish.

One method for measuring added fish is to calculate the natural return ratio (NRR), which is the ratio of the number of native, naturally produced fish divided by the total number of naturally spawning fish (hatchery plus naturally-produced fish) in the previous generation (Busby et al. 1994). Viable salmon populations that are sustaining themselves should have an average NRR of one.

The third component is population structure. Population structure is important because structural changes in the population may impact the population's evolution and its ability to adapt to habitat changes (NMFS 2000). Severe changes in key habitat areas may lead to higher probabilities of extinction, which are not apparent from simply quantifying fish abundance (Hanski et al. 1996). It is important that habitat patches exist in a similar diversity and area to what was present historically in order to support population structure and persistence (NMFS 2000). Loss of a key habitat type may impact the structure of the population without decreasing total numbers of fish. An example would be the loss of habitat supporting natural yearling chinook within a watershed, while other life history strategies continue to persist at stable levels. Population structure can be assessed by looking at life history variations, distribution and types of habitat patches, spatial distribution of abundance, migration corridors, and access to unique habitat areas (NMFS 2000).

The fourth component for a viable salmon population is diversity. Diversity is the genetic variability that occurs in a population, which contributes to protecting a population from short-term environmental changes. Genetic variability (diversity) also helps a population increase its fitness by allowing for adaptation to the special environmental conditions within its specific habitat areas. There should be levels of variation within the population that reflect historic levels and allow for buffering against environmental variability.

In summary, each component is important for having a viable salmon population and these four components depend on properly functioning habitat that exists in similar complexity and area to what was found historically.

For an ESU to recover, there must be a reduction in the factors of decline to a point where risk to the ESU is unlikely (NMFS 2000). Many of the populations within the ESU need to be recovered and restored to a properly functioning level (NMFS 2000). Recovered populations need to be distributed throughout the geographic range of the ESU and recovered populations should represent the major life history patterns and major genetic groups within the ESU (NMFS 2000).

2. Future Pattern of Fisheries

Co-managers will develop recovery goals for Stillaguamish chinook salmon expressed in terms of the four components described above: abundance, productivity, population structure, and diversity. Specific values of the recovery goals will be derived from models relating restored habitat conditions to these components. Based on the historical condition of chinook salmon in the system, recovery to historical levels should result in healthy, harvestable populations.

Once recovery has occurred, fishery plans will be designed with the following principles in mind:

- Harvest-related mortality rates will be at or below levels that would jeopardize the ability of the populations to maintain themselves in a healthy condition without human intervention.
- All sources of harvest-related mortality will be considered in developing and evaluating harvest management plans.
- Harvest management plans will include risk buffering, such that the probability of overharvest in any one year or on any one brood is held to a low level.
- Harvest management goals will be designed so that important population characteristics, such as average fish size, age distribution, geographic distribution of escapement, adult timing distribution, etc. will not be considerably altered due to harvest-related mortality.
- Harvest levels or rates may be as high as the level that will, over the long term, provide the maximum level of harvest, given the above constraints. This will define the maximum sustainable harvest (MSH) for this management unit.

3. Future Hatchery Operation Plans

In the draft CCMP, both current and future hatchery operation plans are explained in detail in Chapter 7. In summary, each facility will be required to complete a comprehensive plan, which includes a detailed description of the facility and program, relationship of the program to other management objectives, and a risk/benefit analysis for stocks of concern as well as implications for the entire ESU.

Future hatchery goals include maintaining the genetic integrity of both natural spawning populations within the Stillaguamish Watershed and the brood stock population used for the natural stock restoration program through continued genetic monitoring.

Creating more natural rearing conditions in the hatchery environment has been demonstrated to reduce the impacts of domestication within the hatchery. The co-managers will work to improve rearing conditions at hatcheries where chinook are reared within the watershed.

The objective of the program is to assist the naturally spawning fish in rebuilding their numbers to a consistent, self-sustaining population that does not require human intervention in order for the population to support directed and incidental harvests. Ultimately, the goal of the natural stock restoration program is that it will no longer be necessary for continued stock survival.

The National Marine Fisheries Service has determined that the Stillaguamish Chinook Natural Stock Restoration Program is one of the six essential hatchery programs within the Puget Sound necessary for recovery of the ESU. Based on NMFS' assessment of population decline and habitat degradation, the North Fork Stillaguamish stock would likely further decline and go extinct without the intervention of the natural stock restoration program (NMFS 1999). Co-managers will determine the future need and size of a chinook hatchery program to meet other management objectives such as the U.S./Canada Indicator Stock Program.

4. Future Habitat Conditions

Maintenance and recovery of the four components necessary for a healthy salmon population depend on properly functioning habitat that exists in similar complexity and area to what was found historically. In order to achieve properly functioning conditions, the following goals must be met:

- Maintain and restore natural watershed processes;
- Maintain a well-dispersed and well connected network of high quality habitat that addresses the needs of all life history stages; and
- Develop, evaluate, and adapt land management activities using monitoring and assessment in order to achieve the objectives listed above.

Habitat Recovery Goals/Properly Functioning Conditions

The ultimate habitat recovery goal is to maintain and restore natural ecosystem conditions that sustain salmonid productivity. To achieve this goal for chinook salmon, individual habitat parameters should meet the following conditions (Where specific citations are not provided the performance targets are based on the professional judgement of the STAG):

a) Sediment

Numerous studies have identified measurable decreases in intra-gravel survival of incubating eggs and alevins as the proportion of fine sands and silts in the streambed increases. Cederholm and Salo (1979), Koski (1972), Phillips (1971), and Reiser and Bjornn (1979) all provide thorough summaries of the effects of sediment on salmonid intra-gravel survival. Fine sediment (<0.85mm) concentrations above 11% can cause a significant reduction in egg-to-fry survival for salmonids. Levels at or below 11% are often encountered in relatively pristine habitats (Peterson et al. 1992).

b) Channel Morphology

Holding habitat in the form of deep, cool pools (<16°C or 61°F) with abundant LWD, is a vital habitat element for chinook because they spend considerable time in freshwater before spawning. Pools provide low velocity areas with overhead cover (depth and LWD), allowing fish to conserve energy reserves and avoid harassment by humans and other predators while sexually maturing. Land use practices (e.g. clearing, logging, and road building) accelerate sediment

delivery into streams, which can result in channel aggradation and pool filling. Plane bed reaches should be returned to forced pool habitat where there are no more than four channel widths between pools on tributary streams. Mainstem habitat on the North Fork Stillaguamish should be increased by 38% to replace lost pool habitat back to 1930s conditions.

Large woody debris is critical in the development of habitat complexity within the stream corridor. Large wood helps to capture sediment, provide cover, and create pool habitat. Large wood volumes and distribution should approximate those found currently in the Nisqually Watershed. Research by Collins et al. (2000) documented considerable shortages of large wood in the Stillaguamish and Snohomish Watersheds in comparison to the Nisqually.

c) Hydrology

The hydrologic regime is a critical watershed process in creating and maintaining suitable habitat conditions. Collins (1997) documented 10 of the largest flows on record during the 1974 to 1994 period. This was a climatic period characterized as dryer and warmer for the Pacific Northwest. Activities such as land clearing, logging, and road building should be improved to return the hydrology of the Stillaguamish Watershed to historical conditions (1928 to 1940 period).

The stability of chinook spawning habitat is equally important. During high flow events spawning gravel can become entrained in the water column and moved downstream, a process known as scour. Egg scour rates as high as 80-90% have been estimated in highly disturbed streams on the Queen Charlotte Islands (Tripp and Poulin 1986). Similarly, scour and resulting sediment deposition was found to have damaged 75% of the chinook redds in a disturbed river system in southwest Oregon (Nawa et al. 1990). Scour has been identified as a considerable source of chinook mortality by Tribal biologists in several Puget Sound and Coastal river basins (NWIFC 1996). The North Fork Stillaguamish River has shown an increasing trend of peak flows, both in frequency and magnitude, resulting in increased chinook mortality (Pess et al. 1999).

Emergent fry prefer shallow, low velocity stream margin and side channel habitats. Chinook fry are frequently stranded and killed due to decreases in water level commonly associated with these habitat types (Phinney 1974; Bauersfeld 1978). In the Stillaguamish Watershed, over-allocation of water rights is a serious concern. Currently, there are 652 cfs of legal water rights in the basin. During low flow conditions, the Stillaguamish Watershed can drop well below this threshold. Chinook salmon are dependent on adequate water, within the stream channel, for all phases of the freshwater portion of their life cycle. Instream flow that meets the upstream migration, holding, and spawning requirements for chinook adults and incubation, emergence, and rearing requirements for the juveniles is fundamental for the continued survival and natural production of this species.

Target flows for the North Fork Stillaguamish should be 700 to 1000 cfs during chinook spawning and 200 to 400 cfs during chinook rearing (Embry 1987). Target flows on the South Fork Stillaguamish for chinook spawning should be 300 to 900 cfs and 100 to 300 cfs for rearing

(Embry 1987). Minimum summer low flows for the North Fork Stillaguamish should be no lower than 300 cfs and for the South Fork Stillaguamish no lower than 200 cfs (Embry 1987).

d) Additional Hydrologic Process and Habitat Condition Considerations:

- Periodic landslides are an important source of coarse and fine sediment delivery. Excessive landslide activity creates unstable channel conditions and the potential for elevated fine sediment levels. Currently, 75% of the landslides within the Stillaguamish Watershed are human induced. The goal for future landslide conditions is to reduce human induced landslide activity by 75% to return to the natural background level.
- Wetlands have key functions within the watershed that include temperature maintenance, sediment and nutrient retention, and flood flow storage. Based on studies by WDOE (1997), 78% of the Stillaguamish Watershed wetlands have been degraded or lost. The target future condition is to restore or create 70% of the lost wetland function to fully functioning status.
- Beaver pond habitat has been decreased by 81% from historic levels. The target future habitat condition is to restore beavers and their associated ponds back to 50% of their historic levels.
- Research has documented the loss of 85% of the estuary/blind channel habitat area from historic levels. The target future habitat condition is to restore or develop 50% of the lost area back to fully functioning estuary/blind channel habitat conditions.

e) Temperature

Preferred water temperature for adult chinook salmon is 12–14°C (54–57°F). Preferred temperature is used to describe the temperature at which, given unlimited acclimation time, a fish will ultimately gravitate toward (Fry 1947). Other studies have shown ranges during migration and spawning of 5.6–13.9°C (42–57°F) and incubation of 5.0–14.4°C (41–58°F) (Bjornn and Reiser 1991). Juvenile chinook prefer temperatures ranging from 7.2–14.4°C (45–58°F) (Bell 1973).

f) Dissolved Oxygen

Bjornn and Reiser (1991) reviewed the scientific literature and concluded that while the threshold for survival is generally low (3.3 mg/l), growth and food conversion efficiency are affected at DO levels of 5mg/l, and that DO levels of 8-9 mg/l are needed to ensure that normal physiological functions of salmonids are not impaired.

VI. RECOMMENDED ACTIONS

A. HATCHERY MANAGEMENT PLAN

1. Goals and General Principles

The goals for hatchery reform are to conserve indigenous genetic resources, assist with the recovery of naturally spawning populations, provide for sustainable fisheries, conduct scientific research, and improve the quality and cost-effectiveness of hatchery programs (Gorton Science Advisory Team 1999).

2. Hatchery Management

A committee of scientists assembled in October 1998 to address the issue of reforming salmon and steelhead hatcheries in Washington State, and developing the following series of recommendations:

- Improve hatchery programs and facilities by implementing comprehensive facility goals based on adult returns and risk assessments for natural stocks.
- Prevent infusion of non-adaptive genes into natural stocks.
- Employ new rearing and release strategies to improve survival and hatchery efficiency. This will allow for separation of hatchery and wild fish in the fisheries and spawning grounds, and discourage the selection of domestic traits within hatchery-reared fish.
- Expand, monitor, and evaluate hatchery programs and their impacts on fisheries and natural spawning populations.
- Conduct research to help increase the survival of hatchery fish in the wild, improve fish health, determine the biological consequences of culturing fish, and increase knowledge regarding the impacts of hatchery fish on wild populations.
- Mark or tag all fish to allow for the identification of hatchery origin fish on the spawning grounds and in fisheries.
- Apply adaptive management for the purpose of testing hypotheses and implementing reforms as a dynamic process.

Implementation of all of the above recommendations is required if salmon and steelhead hatcheries are going to contribute positively to the recovery process and continue to provide fishing opportunities for residents of Washington State and the Pacific Northwest.

Hatchery goals will increasingly be judged on how well they integrate the goals of harvest management, salmon recovery, habitat protection, and the protection of other native species. The increasing emphasis on natural production and ecosystem restoration means that the potential ecological effects of hatcheries, from providing carcasses for nutrients to competing with natural fish to confounding the efforts to measure habitat productivity, will become increasingly important in judging whether hatcheries are successful (NWIFC 1999).

3. Recommended Actions to Achieve Future Hatchery Conditions

The following is a list of actions (not in priority order) developed to address the recommendations of the Gorton Science Advisory Team on Hatcheries, Comprehensive Chinook Process, and the local watershed scientific/ technical recovery team.

- Complete the detailed hatchery operation plans and risk assessments for the current hatchery programs within the watershed.
- Determine stock productivity and habitat capacity for the North Fork chinook.
- Continue the 100% tagging of program fish and the monitoring of natural spawning populations.
- Improve the survival of program fish by making specific physical plant improvements to both the Tribe's Harvey Creek Hatchery and the WDFW Whitehorse Hatchery rearing ponds, and by developing more natural rearing conditions at both hatcheries through the introduction of predator exposures and large wood and substrate.
- Evaluate the efficiency of culling hatchery strays from other watersheds out of the brood stock population.
- Evaluate the option of multiple release site locations within the North Fork Stillaguamish to reseed underutilized, higher quality tributary habitat.
- Evaluate estuary/near shore food production and habitat relationships to outmigrant survival for improving better release strategies for program fish.
- Set the target NOR escapement goal for the North Fork Stillaguamish at 700 fish per year for four consecutive years. Upon reaching this goal, the natural stock restoration program would be terminated to evaluate the ability of the natural spawning population to rebuild itself to self-sustaining levels.
- If spawning escapement of naturally produced fish to the North Fork falls below 500 for four consecutive years, the co-managers will evaluate expanding the scope of the current natural stock restoration program to preserve the genetic diversity of the population.
- Co-managers will evaluate the need for continuing a separate hatchery program for North Fork Stillaguamish chinook to meet U.S./Canada Indicator Stock management objectives. Currently, there are no other stocks that can be used as surrogate indicator stocks for Stillaguamish summer/fall chinook.
- Co-managers will monitor South Fork Stillaguamish chinook for current population trends and negative changes. Further analysis and monitoring of the South Fork stock composition, population size, and straying factors will be implemented.
- Co-managers will develop an overall spawning escapement methodology that accurately reflects adult returns to the watershed.

B. HARVEST MANAGEMENT PLAN

1. Goals and General Principles

Consistent with the overall goal of the Stillaguamish Chinook Salmon Recovery Plan, harvest of chinook salmon will occur in a manner that will have a high probability of not impeding the capability of all natural stocks in the system to rebuild to levels that will support directed harvest and other benefits. The following general principles guide the details of the plan:

- Harvest management alone cannot rebuild Stillaguamish chinook stocks. Instead, it must work together with the management of artificial production and habitat in order to create a viable rebuilding plan.
- Development of an appropriate harvest management plan will require better knowledge of our production function. The appropriate production function relates the biomass of adult fish to the biomass of fertilized eggs deposited in the spawning grounds. This approach will require collection of new information and development of new production models, which may result in new escapement goals; for example, based on the number of females or biomass of eggs rather than the number of fish.
- Before a new production function is derived and a new harvest management plan developed, it is recognized that current management objectives (whether based on fixed goals or ERs) can skew spawning populations toward males and younger and smaller females. Therefore, immediate steps should be taken to assess and reduce, where necessary, the size and age selectivity of fishery-related impacts.
- All sources of fishery-related mortality are considered equally in assessing the ER. These include: preterminal fisheries directed at chinook such as those in Canada and in the ocean off of Washington State; preterminal fisheries with incidental mortality of chinook such as the north Puget Sound sockeye fishery; recreational fisheries directed at chinook such as the Puget Sound winter blackmouth fishery; hook-and-release mortality in selective recreational fisheries; incidental harvest of Stillaguamish chinook in terminal fisheries directed at hatchery stocks; etc. All mortality will be assessed in terms of AEQ mortality, stated as the reduction in the number of adult fish (or biomass of eggs in the new model) that could reach the spawning grounds in the absence of fishing⁵.

2. Interim Harvest Management Plan

The interim harvest management plan will be implemented concurrently with data collection and modeling to develop a new production function and harvest management plan.

⁵ A formula for AEQ exploitation rate is $(R-E)/R$, where R is the total number of fish (or biomass of eggs in the new model) that would have returned to spawn naturally in the absence of fishing and E is actual number (or biomass of eggs) that did spawn naturally given the fishing pattern.

The interim harvest management plan has several key components: 1) maintain the ER (including all sources of fishery-related mortality) on each brood below a maximum level, set so that harvest will not impede the ability of the stocks to rebuild; 2) maintain natural spawning escapement for each stock above a minimum level to assure the continued viability of the management unit; 3) reduce fishery-induced size and age selectivity; and 4) continual evaluation of harvest management and adaptation of the plan based on this information.

Maximum Exploitation Rate

The ER includes all fishery-related mortality (in terms of AEQs) for all fisheries impacting Stillaguamish chinook. During the rebuilding period, this rate should be a rate that is: 1) sustainable under current conditions of freshwater and marine survival; 2) low enough to have a high (>80%) probability of not impeding the ability of the Stillaguamish chinook stocks to rebuild, assuming appropriate habitat protection and restoration actions are implemented; and 3) not unduly constrained below the level necessary to achieve 1 and 2 above.

Although the PSSMP (*United States v. Washington*, 626 F. Supp. 1405, 1985) establishes MSH as the normal management objective for primary natural management units, it is recognized that the interim plan for Stillaguamish chinook may not meet this objective. Therefore, for the duration of the interim plan the overall harvest of Stillaguamish wild chinook may be less than the maximum sustainable level.

Collection and analysis of a system's capacity and productivity for chinook salmon and the development of new exploitation and escapement objectives based on biomass of eggs is a necessary prerequisite to developing a long-term harvest plan that will yield MSH. Current information indicates that the system's capacity for chinook salmon production may be below the level that could be supported by a natural escapement of 2,000 fish. Assessment of the system capacity will be critical in further development of a rebuilding plan, including harvest management, supplementation, and habitat improvement components.

Under the interim plan, the maximum ER will be based on the best available science and updated when new information becomes available. Initially, a rate of 30% AEQ fishery-related mortality (by brood year) will be used as a maximum rate. It is understood that due to size and age selectivity of fisheries and the varying fecundities for chinook of different ages, this rate is equivalent to a higher rate measured in terms of potential egg biomass.

Minimum Escapement Level

Despite the ceiling on the ER, if the projected natural escapement of naturally produced fish to the North Fork falls below a minimum of 500 fish, further harvest restrictions will be implemented to raise the expected escapement above, or as close as possible to, 500 fish.

Reduce Fishery-induced Size and Age Selectivity

There will be a reduction in size and age selectivity merely as a consequence of the reduction in ERs mandated by the interim plan. Monitoring of fish sizes and ages in fisheries and spawning

populations should allow us to assess the degree to which this is occurring. In addition, the following management measures should be evaluated, which might further reduce selectivity:

- Mark all hatchery-produced chinook with a visibly identifiable exterior mark and prohibit the retention of unmarked fish in all Washington, Oregon, and southern BC recreational fisheries.
- Implement pulse fishing (e.g. only being open in alternate years) in certain large scale directed chinook fisheries known to be age and size selective (such as the Canadian troll fishery).
- Investigate the effects of year-round fishing for chinook salmon in Puget Sound, especially fisheries targeting immature chinook.
- Investigate the effects of the use of only large mesh gear in gillnet fisheries directed at wild chinook stocks. When these fisheries become allowable, consider requiring variable mesh gear.
- Investigate the effects of minimum size limits in hook-and-line fisheries.
- Investigate the effects of smolt and shaker captures.

Continual Evaluation of Harvest Management

Annual evaluation of harvest management will have several aspects: 1) assessment of spawning escapement numbers (in terms of NORs) and age and sex composition for each natural stock in the system; 2) assessment of the ER on each age class in all fisheries; and 3) assessment of age or size selectivity in key fisheries impacting Stillaguamish chinook. Details will be included in the monitoring and evaluation section of this plan.

3. Development of A Long-term Harvest Management Plan

A program to collect and evaluate information necessary to develop a long-term harvest management plan for Stillaguamish chinook will continue. The plan will be based on updated assessments of the system productivity and capacity. The most important part of the plan will be production functions for each stock relating recruitment biomass to the biomass of fertilized eggs on the spawning grounds. The long-term harvest management plan will be designed to provide long-term MSH for the entire management unit, under the constraint that the viability and diversity of the production of each stock will not be jeopardized. This program may use information collected as part of regular monitoring, but it may also include special monitoring or assessment beyond the monitoring program.

C. HABITAT MANAGEMENT PLAN

Habitat management is a major component of chinook recovery in the Stillaguamish River Basin. It requires an understanding of the relationships between land use practices and watershed-scale processes, watershed-scale processes and habitat, and habitat and chinook salmon requirements. In order for it to be effective, habitat management must be based on the best available scientific data. Improvement in our knowledge must lead to changes in policies, regulations, social behavior and land use practices. Preservation, restoration, and enforcement actions, as well as further data collection and research are necessary elements in addressing habitat problems that have developed due to poor land use practices.

Historical information is an important guide for protection and restoration actions. Historical documentation clarifies the causes of habitat degradation and creates a reference of desired conditions resulting in a template for salmon recovery. The context of lost salmon habitat and production can help land managers to set clear and attainable restoration goals (e.g. Sedell and Luchessa 1982; Allen and Hoekstra 1987; Newbury and Gaboury 1988; Beechie et al. 1994; Pess et al. 1999). Stillaguamish chinook stocks evolved to the suite of habitat conditions available in the watershed, thus maximizing productivity. Conversely, habitat modifications associated with land use have lowered production potential. Restoration and reconnection of lost habitat and related watershed functions will play a major role in the recovery of endangered and threatened stocks.

1. Habitat Recovery Objectives

- Maintain and restore natural watershed processes.
- Maintain a well-dispersed and well-connected network of high quality habitat that addresses the needs of all life history stages.
- Develop, evaluate, and adapt land use activities using monitoring and assessment in order to achieve the objectives listed above.

2. Habitat Problems

Habitat problems generally result from the interaction between land use practices and natural processes, which occur when direct human impacts (e.g. dikes, logging, road building, and urbanization) disrupt the natural processes that create and maintain habitat (e.g. increased peak flow magnitude and frequency). This can result in the loss and degradation of (not in priority order):

- a) Riparian/shoreline/floodplain vegetation and LWD recruitment.
- b) In-channel and off-channel freshwater rearing habitat.
- c) Estuary rearing habitat.
- d) Spawning habitat.
- e) Large, deep holding pools with adequate cover.
- f) Water quality (e.g. turbidity, temperature, and DO).

In order to address the above problems and facilitate chinook recovery, recovery actions directed toward the root causes need to occur. For the purposes of this report, these actions are categorized as protection, enforcement, and restoration. These actions should occur concurrently in order to achieve recovery.

3. Categories of Recovery Actions

Protection

Habitat protection is necessary to safeguard and restore impacted or high quality habitat against degradation and additional losses. Actions that provide protection include acquisition as well as the revision and enforcement of aquatic and land use regulations. Enforcement of existing and proposed regulations is essential in reaching the goals of a recovery plan. Lack of enforcement personnel and funding is a significant contributor to current poor habitat conditions. Jurisdictions must have the capacity to enforce regulations in order to prevent further loss and degradation of chinook salmon habitat. Areas that are threatened by development, have high restoration potential, or maintain ecosystem connectivity are priorities in this category.

In order to achieve adequate protection, an identification and acquisition strategy should be followed. Initially, an inventory of riparian habitats adjacent to channel segments occupied by chinook salmon should be refined based on existing assessments and new information. This will lead to the development of a priority list for acquisition. Acquisition of critical habitat using fee simple or conservation easements should follow. Protection should focus on maintaining ecosystem connectivity and be implemented over a short time period. Protection and restoration applied together are more likely to increase population productivity and diversity. Regulatory protection should be used in high quality habitats where owners are not fully prepared to relinquish property rights, or in advance of future acquisitions.

Aquatic and land use regulations must be implemented to address human related activities in the watershed, which directly and indirectly harm chinook, their habitat, and key habitat-forming processes. Regulatory actions must include consideration of local, state, and federal regulatory frameworks that provide protective measures for riparian/floodplain and near shore habitats. The following regulatory programs and procedural guidelines should be assessed with the intent to revise where necessary and increase compliance:

- Shoreline Master Plan:
 - Protect tidal influences and riparian areas.
 - Prevent modifications (bulkheads, levees and dikes) and LWD removal.
 - Remove exemptions for single-family dwellings.
- Hydraulic Code:
 - Protect existing fish access and tidal influences.
 - Prevent additional surface and groundwater withdrawals in sensitive areas.
 - Protect naturally functioning systems from polluted groundwater infiltration.

- Stormwater Management upgrades:
 - Prevent increase in sediment transport.
 - Retrofit/redesign infrastructure to decrease sediment and flow effects.
 - Prevent increase in stormwater flow frequency and transport.
- Critical Areas, Sensitive Area, and Grading Ordinances:
 - Protect riparian areas and wetlands with the goal to create properly functioning condition in > 80% of historic wetland, estuarine, and near shore reserves.
 - Prevent LWD removal.
 - Prevent resource extraction or development in critical areas.
 - Require that > 80% of stream shorelines have buffer widths > 1 SPT height (NMFS 1996a).
 - Require mature forest stand thresholds by sub-basin.
- Zoning, Comprehensive Plans, and the Growth Management Act:
 - Implement impervious surface thresholds by sub-basin.
 - Prohibit incompatible floodplain land uses such as bank hardening.
 - Implement zoning thresholds that meet natural landscape attributes.
 - Encourage natural floodplain processes.
 - Assess and revise planned residential development guidelines/exemptions.
 - Require landslide hazard map usage for planning forest use and development.
 - Provide incentives for development design techniques with less impervious surface.

In addition to the above regulatory measures, Best Management Practices (BMPs) are recommended for commercial farmland and small rural landowners as a means to:

- Prevent negative water quality effects from livestock, ditches, nutrient management, municipal water treatment, and field production.
- Prevent future loss of riparian vegetation.
- Re-vegetate riparian areas.
- Remove unnecessary bank armoring.

Increased compliance to existing and future regulations should be pursued. This should include, but not be limited to, hiring additional enforcement officers, increasing inter-jurisdictional cooperation, uncoupling enforcement from politics, and setting severe penalties for violations.

Restoration

Habitat restoration is another necessary step toward the recovery of threatened chinook salmon stocks. Effective restoration actions target production bottlenecks and work with natural processes that produce and maintain habitat. Restoration can lead to increased habitat capacity and diversity, thus increasing chinook productivity. Some restoration projects have immediate results (e.g. culvert replacement), while others may take a century to achieve the desired results (e.g. planting a riparian forest). Restoration actions as part of a recovery strategy should include but not be limited to:

- Decommission roads, particularly in landslide hazard areas.
- Stabilize existing fine sediment sources, particularly the Hazel, Gold Basin and DeForest Creek slides.
- Remove dikes, levees, and revetments to restore natural wood recruitment, channel migration, and floodplain/side-channel connectivity.
- Maintain and upgrade detention facilities to allow increased settling and filtering of fine sediments.
- Enhance riparian forests to restore appropriate natural vegetation and rates of wood recruitment for the site conditions.
- Reconnect and restore degraded wetlands to increase fine sediment filtration, groundwater recharge and stormwater retention.
- Purchase water rights, prioritizing sub-basins with current and projected future flow problems.
- Decrease road densities in forestry areas to less than 3.1 km/km² (1.9 miles/square mile) (NMFS 1996a).
- Disconnect road drainage networks from stream channel networks.

4. Recovery Action Framework

This framework for chinook recovery promotes the protection, enforcement, and restoration strategies introduced above. The report targets specific natural process problems and human impacts that contribute to each habitat problem and outlines a recovery strategy. In addition, performance targets are stated as criteria to measure the desired properly functioning habitat condition (Where specific citations are not provided, the targets are based on the professional judgement of the STAG).

a) Loss and Degradation of Riparian/Shoreline/Floodplain Vegetation and LWD Recruitment

Natural Process Problems

- Reduced riparian function
- Increased sediment supply
- Reduced wood recruitment
- Increased water temperatures
- Increased peak flows
- Modified base flows

Human Impacts

- Deforestation
- Road construction and inadequate maintenance
- Conversion of forestry lands to agricultural and residential areas
- Clearing and grading

- Dikes, levees, and revetments
- LWD removal
- Livestock grazing and trampling of native vegetation

Problem Description

Riparian, shoreline, and floodplain habitats have been continuously altered, to a large extent, since the late 1800s. First by logging and agricultural interests, and more recently and in the future by urban and rural development interests. Historical and current manipulation (e.g. clearing and grading) of riparian/shoreline/floodplain habitats has resulted in a loss of rearing and spawning areas, as well as loss of ecosystem functions that are important to chinook salmon production (e.g. nutrient cycling, LWD recruitment, microclimate control, sediment trapping, and food production).

Manipulation of riparian/shoreline/floodplain habitats also has resulted in increased surface, bank, and shoreline erosion and the consequent disconnection of riparian functions from aquatic systems. Loss and degradation of riparian and floodplain habitats can also be linked to a reduction or elimination of flood events. Flood events provide a source of groundwater recharge, and can deposit and release both sediment and nutrients. Although, flooding can remove riparian vegetation and destroy in-channel habitat, it can also lead to the creation of riparian diversity and in-channel habitat.

Recovery Strategy

- Restore connections to side channels and off-channel habitats.
- Enhance riparian features in locations where poor riparian conditions are present.
- Inventory existing levees and dikes and evaluate them for removal, relocation, or vegetation enhancement.
- Promote the development and retention of mature forest characteristics in floodplain and stream corridors.
- Implement BMPs on farms.

Performance Targets

- 80% of stream shoreline (contiguous area within the channel migration zone or ordinary high water mark) has buffer width greater than one SPT height.
- Greater than 50% similarity of existing riparian and wetland vegetation to natural composition (NMFS 1996a).
 - Maintain cumulative sub-basin total impervious surfaces below 7% (Spence et al. 1996).
 - Annual hydrograph displays characteristics of baseflow and flow timing comparable to historic (1870) watershed conditions.
 - Maintain cumulative sub-basin total of forest age class 0-20 years below 12% (Nichols et al. 1990)

b) Loss and Degradation of In-channel and Off-channel Rearing Habitat

Natural Process Problems

- Increased peak flow magnitude and frequency
- Decreased summer base flow
- Increased sediment supply
- Decreased channel migration
- Decreased riparian function/LWD abundance and recruitment

Human Impacts

- Development (urban/rural residential, industrial, agricultural, infrastructure), clearing, and grading within floodplain and riparian areas.
- Deforestation and road construction
- Road, railroad, and utility crossings
- Dikes, levees, and revetments
- Impervious surface
- LWD removal
- Wetland filling and draining

Problem Description

The loss and degradation of in-channel and off-channel rearing habitat can be linked to processes that have been altered on a watershed scale, as well as processes and functions that operate proximally to rearing habitat. Hydrologic regime alterations within the Stillaguamish Watershed caused by deforestation, road building, wetland loss, and impervious surfaces have led to decreases in quantity and quality of habitat space (e.g. reduced baseflows, increased sediment supply), and have led to rapid changes to habitat space (e.g. increased frequency of peak flows). Restricted channel migration caused by bank hardening, decreases the availability of off-channel habitat, in-channel cover, and prevents the creation of new off-channel habitat. Rearing habitat has also been lost due to the destruction of beaver and beaver habitat. Within the anadromous zone of the Stillaguamish River Basin, 81-94% of the historic beaver pond area has been lost (Pollock and Pess 1999). Finally, riparian zone clearing reduces the quality and quantity of rearing habitats by increasing stream temperature, altering the food supply, and reducing woody debris recruitment, which provides a pool forming function, cover, and nutrients.

Recovery Strategy

- Maintain and restore mature forested cover over at a minimum of 60% (Nichols et al. 1990) of the basin.
 - Reduce forest harvest rates and surface area cut within the watershed.
 - Transition to longer rotations between timber harvest to increase age class and stand size of timber being harvested.

- Reduce road densities and improve road maintenance.
- Reduce conversion of timberland to other land use categories (e.g. agriculture and residential/commercial development).
- Maintain and reduce impervious surfaces on a sub-basin scale to less than 7% TIA (NMFS 1996a).
- Restore connections to side channel wetlands, side-channels, and small streams.
- Restore lost wetland and pond area.
- Reforest and enhance riparian features in locations where poor riparian conditions are present.
- Remove existing impediments to channel migration and prevent new ones in order to restore channel complexity and LWD recruitment.
- Restore channel migration.
- Set back existing dikes and levees and incorporate LWD.

Performance Targets

- 80% of existing off-channel habitat is accessible at stream discharge, which is less than a five-year return interval (NMFS 1996a).
- Shoreline hardening or overwater structures less than 10% of shorelines (NMFS 1996a).
- 80% of historic floodplain wetlands and riparian zone is present (NMFS 1996a).
- Large wood recruitment (*Wild Salmonid Policy* 1997; WFPB 1997; Point No Point Treaty Council and WDFW 1999).
 - 2-4 pieces of LWD/channel width (>20 m or 66 ft channel width).
 - Greater than 0.5 pieces of LWD/channel width (10-20 m or 33-66 channel width).
 - Greater than 0.3 pieces of LWD/channel width (<10 m or 33 ft channel width).
 - Average tree stand diameter greater than 50 cm (20 in) diameter breast height.

c) Loss and Degradation of Estuary and Near Shore Habitat

Natural Process Problems

- Restricted tidal exchange and flushing
- Decreased riparian function/LWD abundance and recruitment
- Decreased channel/shoreline migration

Human Impacts

- Dikes, levees, revetments, and bulkheads
- Road, railroad and utility crossings
- Tide-gates, flood-gates, pump-stations, weirs, and culverts
- LWD removal
- Construction upon and deforestation of marine bluffs

- Wetland filling and draining
- Agricultural activities
- Industrial development

Problem Description

Juvenile salmonids use estuary habitat for feeding, seawater acclimation, refuge from predators, and holding areas until offshore conditions become more favorable (Dorcey et al. 1978). Between 1870 and 1968 approximately 85% of the Stillaguamish tidal marsh was converted to agriculture. Habitat and habitat forming processes have been heavily modified through diking, wood removal, and many other forms of development.

Recovery Strategy

Actions focus on the restoration and enhancement of lost or degraded estuarine habitat areas and conditions preferred by chinook juveniles:

- Remove existing levees, dikes, and revetments.
- Set back dikes, incorporate LWD, and reforest.
- Increase the abundance and recruitment potential of LWD within the estuary.
- Restore connectivity to disconnected estuary wetland habitats.
- Enhance or reconstruct where appropriate estuary wetland features such as blind tidal channels.
- Increase the quantity and quality of salt marsh and riverine tidal forest.
- Reduce water quality pollutants entering the estuary.

Performance Targets

- 80% of historic estuarine and near shore reserves are intact.
- 80% of historic mudflats are present.
- Greater than 50% similarity of existing estuarine vegetation to historic composition.
- Large wood recruitment.

d) Loss and Degradation of Spawning Habitat

Natural Process Problems

- Increased peak flow magnitude and frequency
- Decreased summer base flow
- Increased sediment supply
- Decreased riparian function/LWD abundance and recruitment

Human Impacts

- Development (rural residential, industrial, agricultural, infrastructure), clearing, and grading within floodplain and riparian areas
- Beaver trapping
- Aggravation of unstable slopes
- Deforestation
- Road construction and inadequate maintenance
- Dikes, levees, and revetments
- Impervious surface
- LWD removal
- Wetland filling and draining

Problem Description

Deforestation, road construction, and to a lesser extent development have altered the delivery and routing of water, wood, and sediment. The resulting degradation of spawning habitat in the North Fork Stillaguamish has been well documented. Peak flows and sediment supplies have increased due to timber extraction and related activities (Pess et al. 1999). High levels of fine sediment intrusion, loss of pool area, and redd scour have also been documented (Pess 1999). Lower egg-to-fry survival rates and smolt production estimates have been correlated with large flood events (Beamer and Pess 1999). Other factors such as the effects of low flows and loss of wood may also reduce spawning habitat quantity and quality.

Recovery Strategy

Actions focus on the restoration of natural hydrologic and sediment regimes, wood recruitment, and channel migration.

- Decommission roads, particularly in landslide hazard areas.
- Stabilize existing fine sediment sources, particularly the Hazel, Gold Basin, and DeForest Creek slides.
- Remove dikes, levees, and revetments to restore wood recruitment, channel migration, and floodplain and side-channel connectivity.
- Maintain and upgrade detention facilities to allow increased settling and filtering of fine sediments.
- Enhance riparian forests to restore appropriate natural vegetation and rates of wood recruitment for the site conditions.
- Reconnect and restore degraded wetlands to increase fine sediment filtration, groundwater recharge, and stormwater retention.
- Purchase water rights, prioritizing sub-basins with current and projected future low flow problems.
- Disconnect road drainage networks from stream channel networks.
- Fund improved road maintenance.

Performance Targets

- Forest road densities less than 1.2 km/km² (1.9 miles/square mile) (NMFS 1996a).
- Less than 10% actively eroding bank (NMFS 1996a).
- 80% of historic wetland reserves are intact (NMFS 1996a).
- Sub-basins TIA less than 7% (Spence et al. 1996).
- Sub-basins greater than 50% forested.
- <20% embeddedness in spawning gravel (NMFS 1996a).
- <12% surface fines (<0.85 mm or 0.03 in) in spawning areas (WFPB 1997).

e) Loss of Large and Deep Holding Pools for Adult Chinook

Natural Process Problems

- Increased peak flow magnitude and frequency
- Decreased summer base flow
- Increased sediment supply
- Decreased channel migration
- Decreased riparian function/LWD abundance and recruitment

Human Impacts

- Development (rural residential, industrial, agricultural, infrastructure), clearing, and grading within floodplain and riparian areas
- Deforestation and road construction
- Road, railroad, and utility crossings
- Dikes, levees, and revetments
- Impervious surface
- LWD removal
- Wetland filling and draining

Problem Description

The potential of pool habitat to act as long term holding areas (e.g. those used more than several days prior to spawning) for chinook salmon and other species, is rated poor in all mainstem segments due to lack of cover and the amount of pool filling observed since 1986 (Stevenson pers. comm. 1994). Snorkel survey observations also indicate a decrease in the quantity of holding pools in the mainstem North Fork Stillaguamish. These observations are supported by research documenting recent large-scale changes in channel morphology in the mainstem North Fork Stillaguamish (Pess and Benda 1994). Particular reaches of the mainstem North Fork Stillaguamish have widened over 100%, and aggraded and degraded up to 2.0 m (6.6 ft) in eleven years (Pess and Benda 1994). Lack of cover, decrease in pool depth, and decrease in pool frequency can also lead to increases in temperature and poaching.

Recovery Strategy

- Increase the amount of LWD (e.g. jams) in rivers and streams, prioritizing chinook habitat.
- Enhance riparian features in locations where poor riparian conditions are present.

Performance Targets

- Large wood recruitment.
- Increasing numbers of deep holding pools.

f) A degradation of Water Quality: Principally Sediment, Turbidity, Temperature and Dissolved Oxygen

Natural Process Problems

- Increased sediment supply
- Increased peak flows
- Reduced riparian function
- Loss of connectivity to wetland and groundwater sources

Human Impacts

- Fecal coliform from agriculture and failing septic and sewage treatment.
- Increased temperature from riparian deforestation, road construction and impervious surface runoff.
- Nutrient loading from dairies, commercial farms, hobby farms, municipal treatment plants, and failing septic systems.
- Sediment loading from timber harvest and road construction.
- Increased heavy metals from stormwater and urban runoff.
- Peak flows from timber harvest and impervious surface.
- Filling and draining of wetlands.

Problem Description

Water quality in the Stillaguamish has been and continues to be degraded from natural and human impacts throughout the watershed. There are 16 reaches in the Stillaguamish Watershed that do not meet federal water quality standards and are listed as impaired waterbodies on the 1998 303(d) list. Parameters listed include: temperature, fecal coliform, DO, ammonia, lead, copper, arsenic, nickel, and turbidity. Sediment from 1,080 landslides in conjunction with increasing peak flows has exacerbated temperature and DO problems, reducing chinook spawning and rearing success. Fecal coliform loading from failing septic systems, sewage treatment plants, and agriculture continues to impact water quality and reduce the viability of the Port Susan shellfish beds (Lenartson pers. comm. 1999).

Recovery Strategy

- Decommission roads, particularly in landslide hazard areas.
- Develop landslide hazard zonation maps.
- Stabilize existing landslides, in particular Hazel, Gold Basin, and DeForest Creek.
- Remove dikes, levees, and revetments to reconnect the river and streams to floodplains and side channels, providing locations where fine sediment can settle and be filtered.
- Upgrade detention facilities to allow increased settling and filtering of fines.
- Enhance riparian features in locations where poor riparian conditions are present.
- Enhance and restore wetlands.
- Implement best management practices on farms.

Performance Targets

- No 303(d) listed impaired waterbodies (NMFS 1996a).
- Seven-day moving average of 10-14° C (50-57° F) in freshwater (Bjornn, T. and D. Reiser 1991).
- Dissolved oxygen exceeding 8 mg/l (Bjornn and Reiser 1991).

D. INFORMATION/DATA GAPS

Current gaps in available information may limit the ability to develop an effective management strategy. As information becomes available, it needs to be incorporated into the management activities of agencies regulating habitat and land use. A comprehensive limiting factors analysis has been completed for the Stillaguamish basin outlining a prioritized list of data and information gaps. Research, which addresses these gaps, should be undertaken as funding becomes available.

1. Data Gaps

Data gaps are identified in this report for the purpose of guiding future inventory and research needs. Although this is a chinook recovery plan, many of the information gaps relate to other listed salmonids. Two sources of data were used to compile this information. The first source is a compilation of data and information requirements taken from the limiting factors analysis for the Stillaguamish Watershed (Washington State Conservation Commission 1999). The Stillaguamish TAG ranked the relative importance of these data gaps into three categories: high, moderate, and low (Table 8).

Table 8. Ranked list of general data and information gaps for the Stillaguamish Watershed.

Relative Priority	Data Information/Gap	Source
High	History of diking (and other hydromodifications) to rank restoration projects	Collins 1997
	Long-term changes to peak flows as a possible result of human causes*	Collins 1997
	Locate levees, dikes, and revetments that are no longer required for restoration	TAG
	Quantify the amount of LWD present in the mainstem to establish baseline conditions to be reassessed periodically	TAG
	Investigate where and how long juvenile chinook rear in riverine environments	TAG
	Quantify the amount of natural bank habitat present within the Stillaguamish mainstem as baseline conditions to be reassessed periodically	TAG
	Investigate the impacts of road density and timber harvest on peak flows, low flows, and spawning success, particularly in the North Fork Stillaguamish	TAG
	Investigate hyporheic conditions in river segments that gain or lose water and how they relate to spawning, juvenile use, or permitting wells	TAG
	Determine percent impervious surface, forest cover within the riparian zone, and hydrologically mature forest per sub-basin	TAG
	Investigate the influence of wetland location within a basin or channel network on peak flows	TAG
	Increase the number of stream gauging locations to provide baseline hydrologic information to inform and assess recovery efforts	TAG
	Determine SPT heights for the Stillaguamish Watershed	TAG
	Compile road network surveys, road density, composition, and hazard zonation*	WDOE 1994
	History and impacts of near shore development	TAG
	Near shore habitat inventory and use by anadromous and forage fish	TAG
	Inventory and analysis of sediment/salt marsh accretion in Port Susan	TAG
	Current impacts of fine sediment in chinook spawning and other select areas	TAG
	Basin-wide, multi-species instream flow study and water rights assessment	TAG
	Compile existing basin-wide physical habitat survey information	TAG
	Prioritization of landslides for restoration efforts and hazard zonation maps	TAG
	Identify high quality habitat for future protection/acquisition opportunities	TAG
	Distribution of salinity/salt wedge in the estuary	TAG

Relative Priority	Data Information/Gap	Source
	Chinook production estimation	Nelson 1999
	Chinook limiting factors	Pess 1999
Moderate	Extent and impact of invasive exotic species in riparian/aquatic habitats	TAG
	Analyze hydrology by sub-basin under different development scenarios to determine whether regulations protect hydrologic processes	TAG
	Investigate the fine sediment contribution and habitat impacts of ditch maintenance activities, agricultural practices, timber harvest, and road networks	TAG
	Investigate methods for altering conveyance systems from surface to shallow subsurface systems	TAG
	Basin-wide nutrient budget	TAG
	Fecal coliform/nutrient sources in relation to DO concentrations for fish	TAG
Low	Use of lakes by coho (and other anadromous fish)	Nelson et al. 1997
	Investigate if low flow conditions are preventing the use of spawning habitat	TAG
	Effects of gravel mining on the river channel and habitat quality	Collins 1997
	Investigate the effect of high water temperatures on chinook	TAG
	Effects of channel widening on habitat quality	Collins 1997
	Data on pesticide use to study potential sources of sediment contamination	WDOE 1994
	Genetic analysis of Stillaguamish sockeye	TAG
	Juvenile salmon stomach analysis in estuary habitats	TAG
	Juvenile salmon residence study in estuary habitats	TAG
	Ambient groundwater monitoring in relation to surface water pollution	WDOE 1994
	Distribution of searun cutthroat and bull trout	USFS 1992

* These projects are linked

The second source of data gaps is derived from the Reach Assessment Tables (July 1997 version) compiled by the SIRC Restoration Subcommittee (Table 9). The SIRC was created in the early 1990s and has broad representation within the watershed. Data gaps developed by the SIRC are specific to select streams (and in many cases specific stream reaches) in the watershed.

Table 9. Data gaps compiled from the Stillaguamish reach assessment tables (SIRC 1997).

Stream Name	WRIA No.	Topic	Proposed Actions
Lower Stillaguamish	5.0001	Fish Use/Populations	Life history dynamics and juvenile use patterns
		Habitat	Effects of Arlington urbanization
Church Creek	5.0019	Fish Use/Populations	Interaction between cutthroat and coho
		Fish Use/Populations	Chum returns and spawning evaluation
		Hydrology	Identify illegal withdrawals
		Water Quality	Temperature and invertebrate monitoring
Pilchuck Creek	5.0062	Habitat	Impact of historic land uses on habitat/fish
		Water Quality	Invertebrate monitoring for water quality
Harvey/Armstrong	5.0126/5.0131	Fish Use/Populations	Steelhead distribution and use
		Habitat	Habitat surveys of instream conditions
		Habitat	Historic land use and fish information
		Habitat	Identify source of sand in the lower reaches
		Fish Passage	Identify fish barrier to Bryant Lake
Lower South Fork	5.0001	Fish Use/Populations	Winter chum usage
		Habitat	Update WDNR hydrology map, including fish barriers
		Habitat/Water Quality	Effects of suburbanization on habitat and water quality
		Water Quality	Water quality monitoring
Jim Creek	5.0322	Habitat	Salmon usage above river mile 4.0
		Habitat	Conduct a watershed analysis
		Water Quality	Fecal coliform sources
Canyon Creek	5.0359	Fish Use/Populations	Presence of and use by juvenile chinook
		Habitat	Rate of recovery from logging impacts
		Land Use	Inventory of forest roads on private lands
Upper South Fork	5.0001	Fish Use/Populations	Contribution of 2-year old coho smolts
		Habitat	Limiting factors analysis: food and nutrients
		Land Use	Forest road inventory
		Fish Passage	Splash dam inventory
North Fork	5.0135	Water Quality	Temperature problems in Perry, Boardman, and Canyon
		Fish Use/Populations	Genetic analysis of sockeye and coho stocks
		Habitat	Baseline habitat conditions in urbanizing areas
		Habitat	Limiting factors for chinook
		Hydrology	Source of low flow problems
		Land Use	Analysis of forest roads
		Land Use	Assess recreational use along middle tributaries
		Land Use	Land use impacts in lower tributaries
		Wetlands	Ground data for storage, temperature, and habitat
		Water Quality	Improve temperature monitoring
		Water Quality	Potential contaminants at Fortson pond

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APPENDIX A - WASHINGTON DEPARTMENT OF FISHERIES (WDF)

HISTORIC RELEASE DATA

Table A. WDF 1953-1974 Release Data.

Facility	Year	Month	Day	Species	Stock Name	Stage	Brood-year	Release Site	Stream Code	Number Released
Skagit	1953	05	12	Spring chinook	Skagit	Fingerling	1952	SF ¹ Stillaguamish	59002	4
Skagit	1953	05	13	Spring chinook	Skagit	Fingerling	1952	SF Stillaguamish	59002	3
Skagit	1953	05	14	Spring chinook	Skagit	Fingerling	1952	SF Stillaguamish	59002	3
Skagit	1953	05	15	Spring chinook	Skagit	Fingerling	1952	SF Stillaguamish	59002	3
Skagit	1954	06	24	Spring chinook	Skagit	Fingerling	1953	SF Stillaguamish	59002	1
Skagit	1954	06	28	Spring chinook	Skagit	Fingerling	1953	SF Stillaguamish	59002	2
Skagit	1954	06	29	Spring chinook	Skagit	Fingerling	1953	SF Stillaguamish	59002	2
Skagit	1954	06	30	Spring chinook	Skagit	Fingerling	1953	SF Stillaguamish	59002	2
Skagit	1954	07	01	Spring chinook	Skagit	Fingerling	1953	SF Stillaguamish	59002	2
Green River	1957	03	12	Fall chinook	Green River	Unfed Fry	1956	SF Stillaguamish	59002	10
Green River	1957	03	12	Fall chinook	Green River	Unfed Fry	1956	SF Stillaguamish	59002	20
Green River	1957	04	02	Fall chinook	Green River	Unfed Fry	1956	NF ² Stillaguamish	50135	39
Issaquah	1957	04	30	Fall chinook	Green River	Fingerling	1956	SF Stillaguamish	59002	10
Issaquah	1957	04	30	Fall chinook	Green River	Fingerling	1956	SF Stillaguamish	59002	10
Skagit	1958	05	13	Fall chinook	Samish	Fingerling	1957	SF Stillaguamish	59002	10
Skagit	1958	05	14	Fall chinook	Samish	Fingerling	1957	SF Stillaguamish	59002	4

Facility	Year	Month	Day	Species	Stock Name	Stage	Brood-year	Release Site	Stream Code	Number Released
Skagit	1958	05	14	Fall chinook	Samish	Fingerling	1957	SF Stillaguamish	59002	73
Skagit	1958	05	15	Fall chinook	Samish	Fingerling	1957	SF Stillaguamish	59002	13
Green River	1960	05	03	Fall chinook	Green River	Fingerling	1959	Stillaguamish	50001	99
Green River	1960	05	03	Fall chinook	Green River	Fingerling	1959	Stillaguamish	50001	10
Green River	1960	05	03	Fall chinook	Green River	Fingerling	1959	Stillaguamish	50001	10
Green River	1960	05	03	Fall chinook	Green River	Fingerling	1959	Stillaguamish	50001	10
Green River	1960	05	04	Fall chinook	Green River	Fingerling	1959	Stillaguamish	50001	10
Green River	1960	05	04	Fall chinook	Green River	Fingerling	1959	Stillaguamish	50001	10
Green River	1961	03	03	Fall chinook	Samish	Unfed Fry	1960	Stillaguamish	50001	12
Green River	1961	03	03	Fall chinook	Samish	Unfed Fry	1960	Stillaguamish	50001	35
Green River	1962	02	16	Fall chinook	Green River	Unfed Fry	1961	Stillaguamish	50001	60
Issaquah	1962	03	07	Fall chinook	Green River	Unfed Fry	1961	NF Stillaguamish	50135	47
Issaquah	1962	03	08	Fall chinook	Green River	Unfed Fry	1961	SF Stillaguamish	59002	47
Issaquah	1963	03	06	Fall chinook	Issaquah	Fingerling	1962	NF Stillaguamish	50135	21
Issaquah	1963	03	06	Fall chinook	Issaquah	Fingerling	1962	NF Stillaguamish	50135	21
Issaquah	1963	03	06	Fall chinook	Issaquah	Fingerling	1962	NF Stillaguamish	50135	21
Issaquah	1963	03	07	Fall chinook	Issaquah	Fingerling	1962	NF Stillaguamish	50135	14
Skykomish	1963	03	04	Fall chinook	Green River	Unfed Fry	1962	SF Stillaguamish	59002	45
Green River	1964	02	18	Fall chinook	Green River	Unfed Fry	1963	SF Stillaguamish	59002	44
Green River	1964	02	19	Fall chinook	Green River	Unfed Fry	1963	SF Stillaguamish	59002	49

Facility	Year	Month	Day	Species	Stock Name	Stage	Brood-year	Release Site	Stream Code	Number Released
Green River	1964	05	18	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	19
Green River	1964	05	21	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	20
Green River	1964	05	22	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	20
Green River	1964	05	22	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	21
Green River	1964	05	25	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	20
Green River	1964	05	25	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	21
Green River	1964	05	26	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	11
Green River	1964	05	26	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	11
Issaquah	1964	02	21	Fall chinook	Green River	Unfed Fry	1963	NF Stillaguamish	50135	31
Issaquah	1964	02	24	Fall chinook	Green River	Unfed Fry	1963	NF Stillaguamish	50135	31
Issaquah	1964	05	12	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	38
Issaquah	1964	05	12	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	82
Issaquah	1964	05	13	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	11
Issaquah	1964	05	13	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	15
Issaquah	1964	05	14	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	50
Issaquah	1964	05	14	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	92
Issaquah	1964	05	14	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	12
Issaquah	1964	05	15	Fall chinook	Green River	Fingerling	1963	Stillaguamish	50001	22
Green River	1965	03	22	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	25
Green River	1965	03	23	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	19

Facility	Year	Month	Day	Species	Stock Name	Stage	Brood-year	Release Site	Stream Code	Number Released
Green River	1965	04	28	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	11
Green River	1965	04	28	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	12
Green River	1965	05	04	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	10
Green River	1965	05	04	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	11
Green River	1965	05	05	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	10
Green River	1965	05	05	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	10
Green River	1965	05	06	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	10
Green River	1965	05	07	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	11
Green River	1965	05	24	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	6
Green River	1965	05	25	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	6
Green River	1965	05	25	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	7
Green River	1965	05	26	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	9
Green River	1965	05	26	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	7
Green River	1965	05	26	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	10
Green River	1965	05	27	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	4
Green River	1965	05	27	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	5
Green River	1965	05	27	Fall chinook	Green River	Fingerling	1964	Stillaguamish	50001	10
Issaquah	1965	04	30	Fall chinook	Green River	Fingerling	1964	SF Stillaguamish	59002	8
Issaquah	1965	04	30	Fall chinook	Green River	Fingerling	1964	SF Stillaguamish	59002	10
Issaquah	1965	04	30	Fall chinook	Green River	Fingerling	1964	SF Stillaguamish	59002	12

Facility	Year	Month	Day	Species	Stock Name	Stage	Brood-year	Release Site	Stream Code	Number Released
Issaquah	1965	05	10	Fall chinook	Green River	Fingerling	1964	SF Stillaguamish	59002	54
Issaquah	1965	05	10	Fall chinook	Green River	Fingerling	1964	SF Stillaguamish	59002	13
Green River	1966	04	26	Fall chinook	Green River	Fingerling	1965	Stillaguamish	50001	30
Green River	1966	04	27	Fall chinook	Green River	Fingerling	1965	Stillaguamish	50001	39
Green River	1966	04	28	Fall chinook	Green River	Fingerling	1965	Stillaguamish	50001	39
Issaquah	1966	05	03	Fall chinook	Issaquah	Fingerling	1965	Stillaguamish	50001	50
Issaquah	1966	05	03	Fall chinook	Issaquah	Fingerling	1965	Stillaguamish	50001	17
Green River	1967	05	02	Fall chinook	Green River	Fingerling	1966	Stillaguamish	50001	44
Green River	1967	05	09	Fall chinook	Green River	Fingerling	1966	Stillaguamish	50001	23
Green River	1967	05	10	Fall chinook	Green River	Fingerling	1966	Stillaguamish	50001	53
Green River	1967	05	11	Fall chinook	Green River	Fingerling	1966	Stillaguamish	50001	26
Green River	1968	05	13	Fall chinook	Green River	Fingerling	1967	Stillaguamish	50001	49
Green River	1969	04	18	Fall chinook	Green River	Fingerling	1968	Stillaguamish	50001	57
Willapa	1969	02	05	Fall chinook	Deshutes	Unfed Fry	1968	Stillaguamish	231001	16
Green River	1970	04	02	Fall chinook	Green River	Fingerling	1969	Stillaguamish	50001	26
Skagit	1970	05	18	Fall chinook	Minter Creek	Fingerling	1969	Stillaguamish	50001	15
Issaquah	1971	04	14	Fall chinook	Green River	Fingerling	1970	NF Stillaguamish	50135	75
Green River	1972	02	17	Fall chinook	Green River	Unfed Fry	1971	Stillaguamish	50001	60
Green River	1972	02	24	Fall chinook	Green River	Unfed Fry	1971	Stillaguamish	50001	72
Green River	1972	03	08	Fall chinook	Green River	Unfed Fry	1971	Stillaguamish	50001	56

Facility	Year	Month	Day	Species	Stock Name	Stage	Brood-year	Release Site	Stream Code	Number Released
Green River	1972	03	09	Fall chinook	Green River	Unfed Fry	1971	Stillaguamish	50001	59
Green River	1972	03	13	Fall chinook	Green River	Unfed Fry	1971	Stillaguamish	50001	34
Skykomish	1973	03	05	Fall chinook	Skykomish	Fingerling	1972	NF Stillaguamish	50135	20
Skykomish	1973	03	06	Fall chinook	Skykomish	Fingerling	1972	NF Stillaguamish	50135	8
Skykomish	1973	03	06	Fall chinook	Skykomish	Unfed Fry	1972	Stillaguamish	50001	27
Skagit	1974	03	11	Fall chinook	Hood Canal	Fingerling	1973	SF Stillaguamish	59002	17
Skagit	1974	03	12	Fall chinook	Green River	Fingerling	1973	NF Stillaguamish	50135	71

¹. SF = South Fork

². NF = North Fork

APPENDIX B - STILLAGUAMISH NATURAL RESOURCES' HISTORIC CWT/RELEASE DATA

Table A. CWT-Applied Data.

Broodyear	Number of Fish	Bar Code	Size	% Tag Retention (after 24 hrs)
1986	24,903	21-22-21	174/lb	N/A
1987	143,989	21-25-55	250/ lb	93.2
1988	41,381	21-31-47	167/ lb	89.0
1989	47,068	21-18-26	135/ lb	96.0
1990	69,341	21-20-26	150/ lb	91.2
1991	178,443	21-22-05	140/ lb	97.0
↓	26,189	21-22-40	140/ lb	97.0
1992	101,217	21-22-51	180/ lb	89.1
1993	216,845	21-23-30	140/ lb	92.8
↓	4,175	21-20-45	120/ lb	92.8
↓	5,490	21-18-56	120/ lb	92.8
1994	212,837	21-26-10	185/ lb	97.1
↓	19,027	21-24-26	185/ lb	95.0
1995	36,089	21-29-54	140/ lb	99.5
1996	218,650	21-29-60	200/ lb	98.7
1997	48,239	21-32-03	110/ lb	98.0
1998	190,814	21-01-52	135/ lb	99.0

Table B. CWT Release Data.

Broodyear	Number of Fish	Size	Release Site	Release Date(s)
1986	23,904	90/ lb	NF ¹ rm ² 21.0	870414
1987	127,910	90/ lb	NF rm 24.5	880515
1988	36,599	80/ lb	NF rm 24.5	890517
1989	44,964	86/ lb	NF rm 24.5	900516
1990	63,019	69/ lb	NF rm 24.5	910517-0520
1991	165,620	85/ lb	NF rm 24.5	920515-0519
↓	24,091	80/ lb	SF ³ rm 64	920522
1992	89,207	80/ lb	NF rm 24.5	930525
1993	200,664	80/ lb	NF rm 24.5	940513-0525
↓	3,855	80/ lb	SF rm 64	940606
↓	5,048	80/ lb	SF rm 64	940606
1994	203,174	70/ lb	NF rm 24.5	950524-0529
↓	15,563	80/ lb	SF rm 64	950525
1995	29,309	50/ lb	NF rm 24.5	960523-0528
1996	202,390	90/ lb	NF rm 24.5	970512-0517
1997	45,295	56/ lb	NF rm 24.5	0514-0523
1998	176,546	84/ lb	NF rm 24.5	0522-0529

^{1.} NF = North Fork Stillaguamish

^{2.} rm = river mile

^{3.} SF = South Fork Stillaguamish

Table C. Total release data.

Broodyear	Total number Untagged (untagged + tag lost)	Total (untagged + tagged)	% Egg to Release Survival
1981		100,000	77
1982		33,000	33
1983		46,410	84
1986	25,996	49,900	55
1987	21,831	149,741	83
1988	4,524	41,123	82
1989	1,873	46,837	78
1990	6,081	69,100	86
1991	11,136	176,756	
↓	1,619	25,710	87
1992	10,914	100,121	44
1993	15,336	216,000	
↓	295	4,150	
↓	386	5,434	75
1994	8,026	211,200	
↓	60,337	75,900	72
1995	6,191	35,500	70
1996	15,702	218,092	73
1997	2,344	47,639	18
1998	14,108	190,654	67

APPENDIX C - ACRONYM LIST

AEQ	Adult Equivalent
BMP	Best Management Practices
BC	British Columbia
CAR	Critical Area Regulations
CCC	Civilian Conservation Corps
CCMP	Comprehensive Chinook Management Plan
CMZ	Channel Migration Zone
CWA	Clean Water Act
CWT	Coded Wire Tag/s
DO	Dissolved Oxygen
ER	Exploitation Rate
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FEMAT	Forest Ecosystem Management Assessment Team
GDU	Genetic Diversity Unit
GIS	Geographic Information System
GMA	Growth Management Act
LWD	Large Woody Debris
MAL	Major Ancestral Lineage
MSH	Maximum Sustainable Harvest
NF	North Fork
NMFS	National Marine Fisheries Service
NMML	National Marine Mammal Laboratory
NOR	Natural Origin Recruit
NRR	Natural Return Ratio
PFMC	Pacific Fishery Management Council
PRD	Planned Residential Developments
PSC	Pacific Salmon Commission
PSSMP	Puget Sound Salmon Management Plan
PST	Pacific Salmon Treaty
SEPA	State Environmental Policy Act
SF	South Fork
SIRC	Stillaguamish Implementation Review Committee
SPT	Site Potential Tree
TAG	Technical Advisory Group
TIA	Total Impervious Area
USFS	United States Forest Service
WDF	Washington Department of Fisheries
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WDOE	Washington Department of Ecology
WRIA	Watershed Resource Inventory Area

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APPENDIX E - GLOSSARY

Adaptive Management	The process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve future management plans.
Adipose-clipped fin	The artificial removal of the small fin immediately behind the dorsal fin. A method of marking individual fish so that they can be identified in subsequent life history stages.
Age zero fish	A fish that is in its first year of life; also know as subyearlings.
Aggradation	The geologic process which raises streambeds, floodplains, and the bottoms of other waterbodies in elevation by the deposition and accumulation of material eroded and transported from other areas.
Alevin	The larval stage of salmonid development that occurs after the egg has hatched, when the juvenile fish lives within streambed gravel up to several months until its yolk sac is absorbed.
Allochthonous	Having originated outside the area in which it now occurs.
Alluvial	Deposited by running water.
Alluvium	Sediment of loose material such as clay, silt, sand, gravel, and larger rocks deposited by running water.
Anadromous	Species that hatch in freshwater, mature in salt water, and return to freshwater to reproduce.

Anthropogenic	Pertaining to the impact of man on nature.
Aquatic insects	Insects that live in water for all or a portion of their life history.
Artificial production	Fish production that depends on spawning, incubation, hatching, or rearing in an artificial production facility such as a hatchery or rearing pen.
Bar	An accumulation of sand, gravel, or other alluvial material formed at any point in a stream channel where a decrease in water velocity induces sediment deposition.
Bedload	Sediment moving on or near the streambed and frequently in contact with the streambed.
Benthic	Living at, in, or associated with structures on the stream bottom.
Benthic Invertebrates	Bottom-dwelling invertebrates, typically aquatic insect larvae.
Best Management Practices	A practice or combination of practices determined to be the most effective and practicable means of preventing or reducing the amount of nonpoint pollution generated by management activities.
Biomass	The amount of living material of an organism, population, or community.
Blackmouth	Juvenile chinook salmon in marine waters.

Brood Stock	Adult salmonids that are destined to be the parents for a particular stock or smaller group of fish.
Bull Trout (<i>Salvelinus confluentus</i>)	Found in the Snohomish River basin in both resident and anadromous forms. Spawning areas are usually associated with cold-water springs, groundwater infiltration, and the coldest streams in a watershed. They may hybridize with Dolly Varden.
Carrying Capacity	Number of individual organisms the resources of a given area can support, usually through the most unfavorable period of the year.
Channel Morphology	The form and structure of a stream channel.
Chinook Salmon (<i>Oncorhynchus tshawytscha</i>)	Also known as king salmon or blackmouth salmon. Chinook are distinguished from other salmon by its large size. The species generally spawns in moderate to large streams and main channels. Chinook are classified as either stream-type or ocean-type and typically live three to six years, but may reach eight years of age before spawning.
Chum Salmon (<i>Oncorhynchus keta</i>)	Also known as dog salmon. Chum spawn in streams of various sizes and the fry generally migrate directly to sea after emergence. They return to freshwater to spawn at between two and five years. Chum salmon are second only to chinook in size.
Coded wire tag	A small wire etched with a distinct binary code that is implanted (usually in the snout) in juvenile fish before they migrate to salt water. This allows for the identification of the origin of the fish when retrieved.

Coho Salmon
(*Oncorhynchus kisutch*)

Also known as silver salmon. Coho are distinguished by black spots on their back and the upper lobe of their tail, and the absence of black pigment along the base of their teeth and lower jaw. This species spawns between October and January in low gradient, small, and moderate-sized tributaries. Coho salmon generally rear in low gradient, small, and moderate-sized tributaries and side channels of mainstem rivers with a large amount of pool habitat. Juveniles spend approximately one year in freshwater before migrating to estuaries and out to sea. They return to freshwater to spawn at between two to five years, during the months of August to November.

Colluvial

Pertaining to rock detritus and soil accumulated at the foot of a slope.

Cutthroat Trout
(*Oncorhynchus clarki*)

Cutthroat trout are generally found in tributaries, side channels, beaver ponds, and slower reaches of mainstem habitat. Cutthroat trout are found in the Snohomish River basin in both resident and anadromous forms.

Degradation

The geologic process by which streambeds and floodplains are lowered in elevation by the hydraulic removal of material.

Delta

An area formed from the deposition of sediments at the mouth of a river

Deposition

The settlement or accumulation of suspended or bed load material out of the water column onto the stream bed or floodplain. It occurs when the energy of flowing water and channel gradient are unable to transport the sediment further.

Discharge	The volume of water flowing in a stream at a given place and within a given period of time, usually expressed as cubic meters per second (m ³ /sec) or cubic feet per second (cfs).
Dolly Varden (<i>Salvelinus malma</i>)	Dolly Varden are a salmon species found in the Snohomish River basin in resident and anadromous forms. They typically live in small tributaries and tend to prefer colder waters. Anadromous forms may live two to three years in freshwater and up to seven years at sea.
Desynchronization	Events that do not coincide or occur simultaneously.
Ecosystem	The biological community and its chemical and physical environment functioning as a system.
Electrophoresis	A technique that analyzes genetic variations in fish body fluids and muscle tissue to determine origin in mixed populations. The process uses charged molecules (e.g. enzymes and proteins) that separate in an electric field.
Endangered Species Act	A 1973 Act of Congress mandating the protection and restoration of endangered and threatened species.
Escapement	Fish that have survived all fisheries and natural predation to make up a spawning population.
Escapement Goal	A predetermined number of salmonids that are not subject to harvest and will be parent spawners for a wild or hatchery stock of fish.

Estuary	A partially enclosed embayment where freshwater and seawater meet and mix.
Evapotranspiration	Sum of the loss of moisture by evaporation from air and water surfaces and by transpiration from plants.
Evolutionary Significant Unit (ESU)	A population or group of populations of a species that is reproductively isolated from other population units, and represents an important component in the evolutionary legacy of the species.
Fingerling	A small fish, usually up to one year of age.
Fish Passage Barrier	Any structure that impedes the upstream or downstream movement of fish at any life stage.
Fishery	The act, process, or occupation of attempting to catch fish, whether they are retained or released.
Fitness	Genetic contribution by an individual's descendents to future generations.
Food Chain	The transfer of food energy from plants to one or more animals; a series of plants and animals linked by their food relationships
Flood Flow	A high rate and volume of water flow that exceeds channel capacity and results in flooding of floodplain areas.

Flooding	The covering or inundation of land with water.
Floodplain	A low level area that may be submerged by floodwaters or an area built up by stream deposition.
Fluvial	Pertaining to a stream or river, or an event produced by stream action.
Fry	Young salmonids that have emerged from the gravel and are up to one month of age.
Gamete	One of two cells (egg or sperm), usually from different parents, that fuse to form a zygote.
Genetic Diversity	Genetic variation within a group or population. Genetic diversity of a species includes both genetic differences between individuals within a population and between populations.
Geomorphology	A science that deals with the structure and origin of land and submarine features on the Earth's surface.
Gradient	Upward or downward slope or rate of elevation change over the horizontal distance of a streambed.
Habitat	Place where a plant or animal lives during all or part of its life cycle.

Herring (<i>Clupea harengu</i>)	Small fish that is found in the temperate and colder parts of the North Atlantic with a subspecies in the Pacific. Along the Pacific coast, these fish typically move into estuaries, bays, and other shallow water to spawn.
Holding Area/Habitat	Area used by fish for rest between periods of activity. Holding areas are generally characterized by low temperatures, cover, flow, or pools formed by rocks, fallen wood, and debris.
Hydric Soils	Saturated soils usually associated with wetland and estuarine habitat.
Hydrology	A science dealing with the properties, circulation, and distribution of water on the surface of the land, in the soil, and underlying rocks.
Impervious Surface	Surfaces that restrict or reduce the infiltration of surface water into soils (e.g. pavement, compacted soils, etc.)
Interspecific	Interactions (e.g. competition) between species.
Interstitial	The small spaces between streambed gravel and other rock formations.
Intraspecific	Interactions (e.g. competition) within a species.

Large Woody Debris (LWD)	Large logs (generally 30 cm or 12 inches in diameter, or larger) and root wads that fall or are placed in or near a stream and become part of the riparian or aquatic habitat.
Life History	A history of the changes through which an organism passes in its development from the primary stage to its natural death.
Lithology	The study of rocks and the character of rock formation.
Log Jams	Accumulation of large woody debris within a stream, which over time can increase in size creating holding areas for salmonid species.
Mainstem	The principal stream or channel for any drainage basin.
Mass Wasting	Landslide processes including debris falls, debris slides, avalanches, debris flows, rockslides, slumps, and collapse of road cuts and fills.
Meander	The turning or winding of a stream.
Metapopulation	Composed of a core (source) population and surrounded by satellite (sink) populations. The core population is usually characterized by high abundance and high habitat quality. Satellite populations fluctuate in size (depending on conditions) and are typically found in less suitable habitat.
Mitigation	To lessen or avoid the effects of a given activity.

Mixed Stock	A stock whose individuals originated from commingled native and non-native parents, or a previously native stock that has undergone substantial genetic alteration.
Maximum Sustained Yield (MSY)	The greatest number or weight of fish that can be harvested without reducing the stock biomass from year to year.
Native Stock	An indigenous stock of fish that has not been substantially affected by genetic interactions with non-native stock or by other factors and is still present in all or part of its original range.
National Marine Fisheries Service (NMFS)	Federal Agency governed by the Department of Commerce, responsible for administering the Endangered Species Act for marine mammals and marine and anadromous fish.
Natural Production	Fish production that is sustained by natural spawning and rearing in natural habitat.
Net Pen	A fish rearing enclosure used in lakes and marine areas.
Nonpoint Source Pollution	Indirect or scattered sources of pollution that enter a water system such as drainage or runoff from agricultural fields, airborne pollution from cropdusting, runoff from urban areas (construction sites, etc.)
Ocean-type	Classification of chinook salmon that migrate out to sea during the first year of life and spend a considerable longer period of time in estuary habitat than stream-type chinook.

Off-channel Habitat	A relatively calm portion of a stream outside of the main flow such as a side channel, slough, dead-end channel, or wetland.
Outbreeding Depression	The reduction in fitness that results from mating between unrelated or distantly related individuals. It may result from loss of local adaptation or from the breakup of gene combinations favored by natural selection.
Outmigration	Movement of young salmonids from freshwater spawning and rearing habitat to estuary and marine waters.
Outplanting	Placement of typically juvenile fish from a hatchery or other watershed into an area where they were not naturally produced. Outplanting can alter the genetic diversity of a stock.
Palustrine Wetland	All non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean derived salts is below 0.5%.
Pelagic	Pertaining to open ocean.
Pink Salmon (<i>Oncorhynchus gorbuscha</i>)	Also known as humpback salmon. Pink salmon are distinguished from other salmon by their two-year life span and a characteristic hump on large spawning males. They are typically the smallest of the Pacific salmon as adults.
Primary Production	The production of biomass usually by green plants and photosynthetic organisms.

Rainbow Trout (<i>Oncorhynchus mykiss</i>)	Resident form of steelhead trout, spending their entire lives in freshwater. Rainbow trout are considered predators on certain life history stages of chinook salmon.
Rain-on-Snow Event	Occurs when warm, moisture-laden air masses pass over snow, causing condensation of water on the snow surface; this process releases large amounts of latent energy, facilitating the rapid melting of substantial volumes of snow
Reach	Any specific section of a stream's length.
Rearing Habitat	Habitat favored by juvenile salmonids for growth and development before migrating to sea. Generally characterized by shady pools and quiet water, ponds, and sloughs.
Recruitment	Addition of reproduction of new individuals to a population.
Redd	Fish nests made in gravel (particularly by salmonids) consisting of a depression that is created and then covered once eggs are deposited.
Resident Salmonid Species	Salmonid species that spend their entire lives in freshwater with no migration to marine waters.
Riffles	A shallow area extending across a streambed causing broken water, often with a fast moving current.

Riparian Habitat	Area along the banks of rivers and streams, provides a transition zone between river and upland habitat.
Rip-rap	Large rocks, broken concrete, or other structure used to stabilize stream banks and other slopes.
River Mile	Distance of a given point (in miles) from the mouth of the river.
Riverine	Pertaining to river or stream systems.
Root Wad	The exposed root system of an uprooted or washed-out tree.
Run	The sum of stocks of a single salmonid species that migrate to a particular region, river, or stream of origin at a particular season.
Salmon and Steelhead Stock Inventory (SASSI)	A cooperative program of the Washington Department of Fish and Wildlife and Washington Treaty Indian Tribes to inventory and rate the status of salmon and steelhead trout stocks on a recurring basis.
Salmonid	Any fish of the taxonomic family Salmonidae, including salmon, trout, char, whitefish, and grayland.
Scour	The removal of material by erosion due to moving water.

Sedimentation	The action or process of forming or depositing sediment.
Side Channel	A channel that typically runs parallel to the main channel, but is still connected. Characterized by lower flows than the main channel.
Siltation	The deposition of suspended materials, usually as a result of reduced water velocity.
Sink Population	Weak subpopulations within a metapopulation which without contributions from strong or source subpopulations will likely go extinct.
Site Potential Tree Height	The average maximum height of the tallest dominant trees (200 years or more) on a given site, depending on soil type.
Slough	A place of deep mud, usually an inlet from a river; a section of abandoned stream channel containing water during all or part of the year. Often a creek in a marsh or tide flat.
Smolt	Young salmon or sea trout that is about two years old and at the stage of development when it assumes the appearance of the adult; undergoing physiological changes allowing for a shift in lifestyle from freshwater to marine water.
Smoltification	The process by which a young salmon converts from a fresh water life stage to marine.

Sockeye Salmon (<i>Oncorhynchus nerka</i>)	Also known as red salmon. Generally, a lake rearing salmon that may spend one to three years in freshwater before migrating to sea. They may spend one to four years at sea before returning to freshwater to spawn.
Source Population	Strong subpopulations of bull trout within a metapopulation, which contribute to weak (sink) subpopulations and will prevent local extinctions.
Spawning	The production and deposition of eggs by aquatic animals. May also include the act of nest (redd) construction and egg fertilization.
Spawning Grounds	Specific stream reaches where spawning occurs.
Spawning Habitat	Area favored by salmonids (in particular) for spawning. Generally characterized by clean gravel and a low percentage of fine sediment.
Stakeholder	Active member/group of a process or interested party.
Stock	A group of fish that is genetically self-sustaining and isolated geographically or temporally during reproduction. Generally, a local population of fish.
Substrate	Mineral and organic material that forms a streambed. Surface upon which an organism lives.

Suspended Solids	Suspended mineral and organic material suspended, but not dissolved by the energy of moving water.
Total Impervious Area	Intended as a combination of areas that have had their infiltration capacity reduced through anthropogenic activities plus areas that naturally contribute to surface water.
Tributary	A stream feeding a larger stream or lake.
Turbidity	Relative water clarity measured by the extent which light passing through water is reduced by suspended and dissolved materials.
Watershed	The total land area that drains to any single river or stream. Also known as a basin or catchment.
Weir	A device placed across a stream to divert fish into a trap, to raise the water level, or to divert its flow. Also, a notch or depression in a dam or other water barrier through which the flow of water is measured or regulated.
Wetland	Areas that have a predominance of hydric soils and that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions.
Yearling	A fish that has lived more than one year and is in its second year of life.